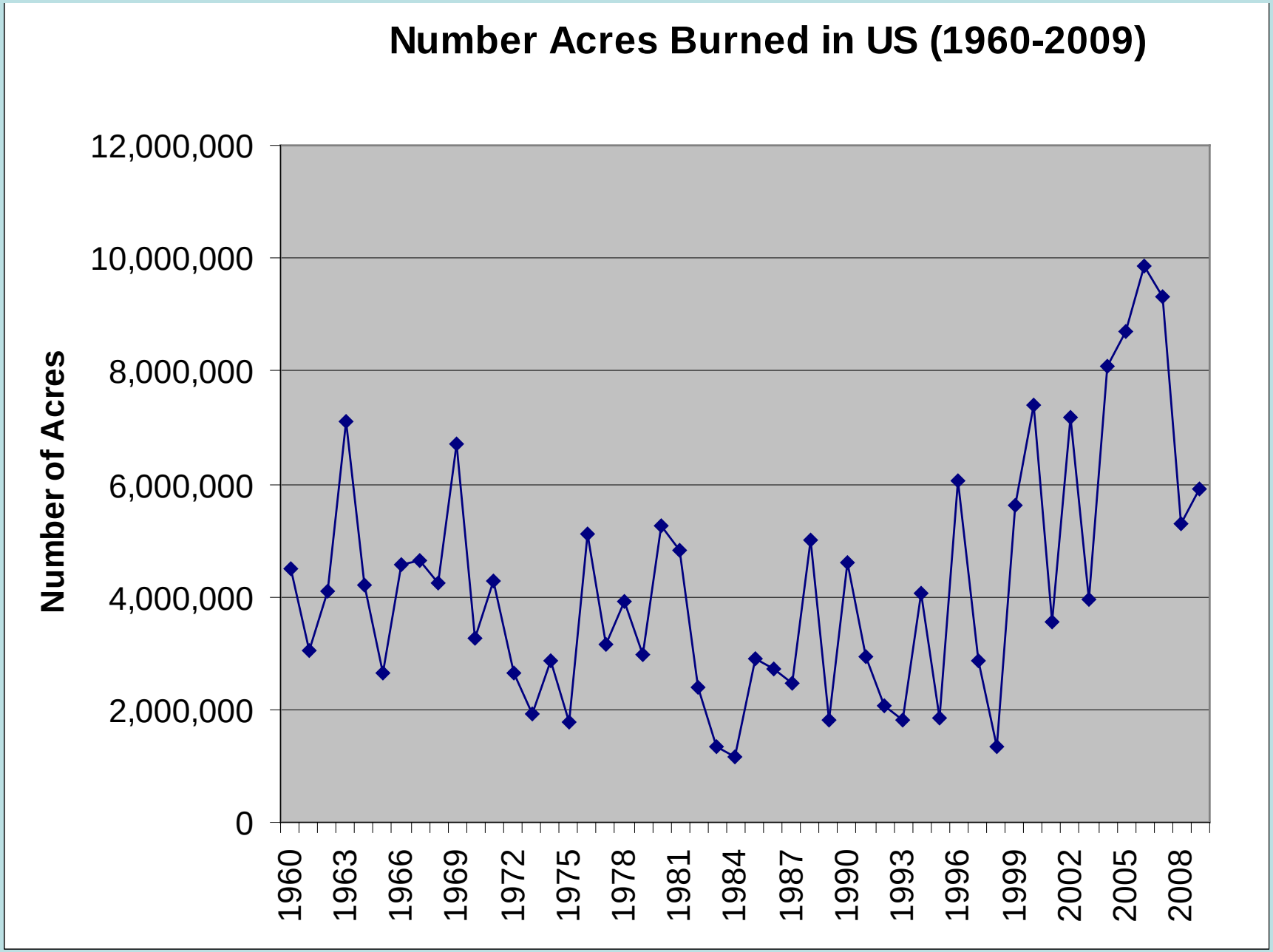
Monitoring Ecological Trends using Landsat Time Series Data: Recent Results and Perspectives

Jim Vogelmann

USGS/EROS

Some Background

- Two long-term multi-year multi-partner projects use Landsat imagery as foundation data for developing products for the fire community
  - Landscape Fire and Resource Management Planning Tools Project (LANDFIRE)
  - Monitoring Trends in Burn Severity (MTBS)
  - Both sponsored by the Wildland Fire Leadership Council (which was established by Secretaries of Agriculture and Interior in support of Federal Fire Management Policy)


Number Acres Burned in US (1960-2009)
Number of Acres
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008

LANDFIRE Background

Objectives

- An assessment of vegetation, fuel and ecosystem condition for the United States.
- Consistent, comprehensive, repeatable.

24 primary data products

•30m nominal resolution nationwide.

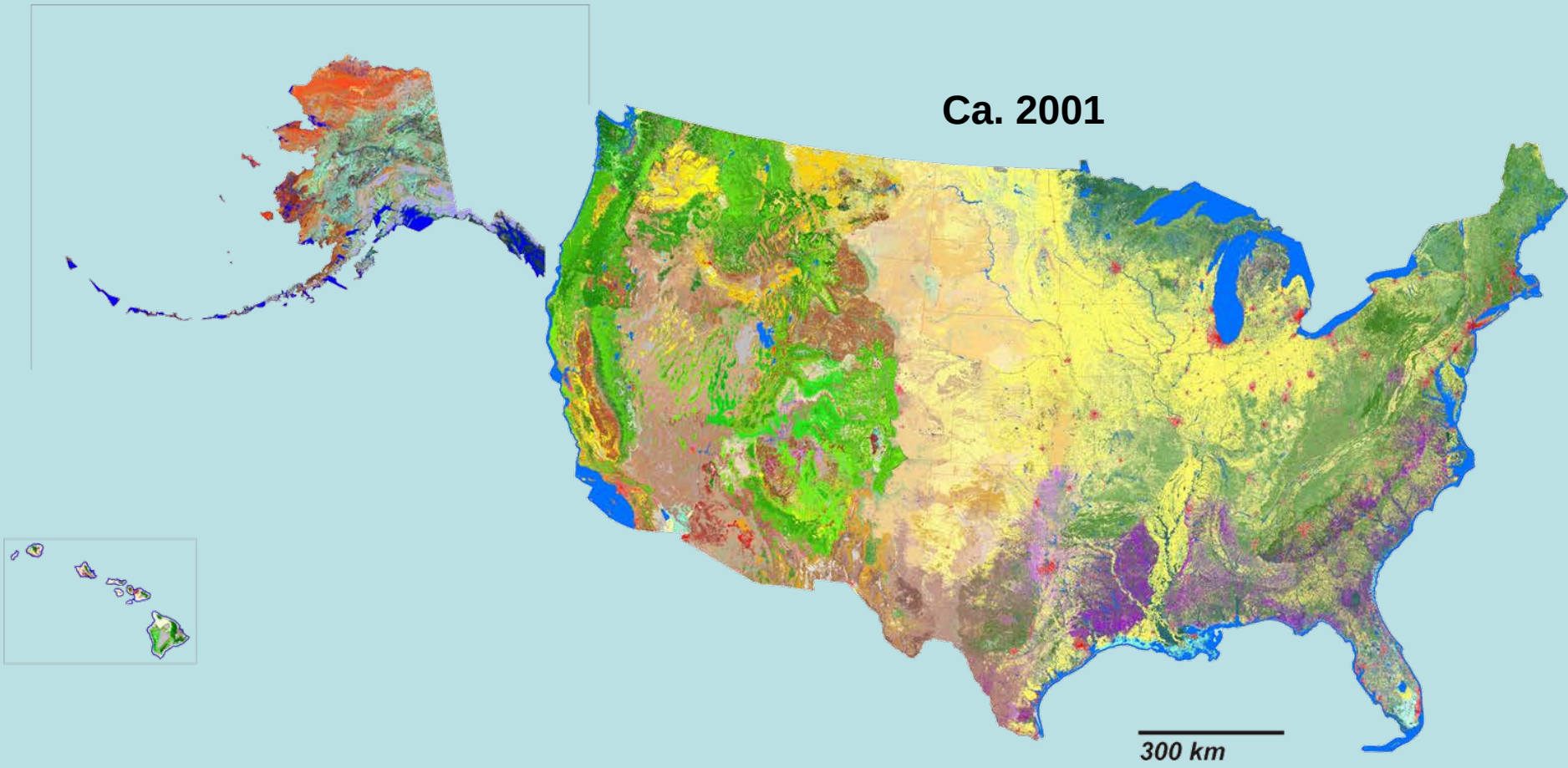
- Vegetation Type
- Fuel (surface and canopy).
- Fire regime condition class (reference conditions, departure from reference conditions; http://www.frcc.gov).

Intended applications

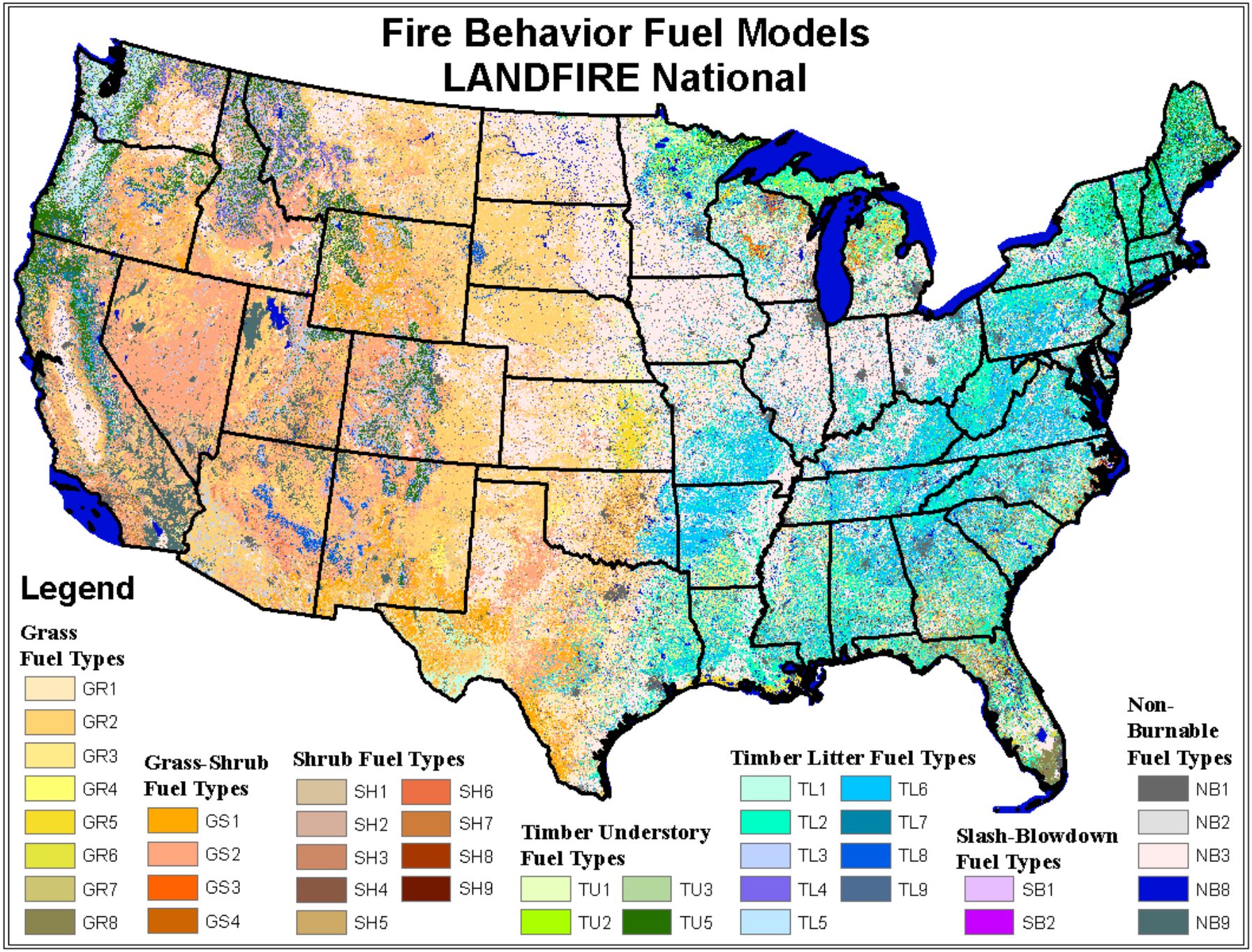
- Fire hazard assessment.
- Fuel and vegetation management.
- National strategic planning
- Incident support.
- Other land management applications (e.g., wildlife habitat).

http://www.landfire.gov

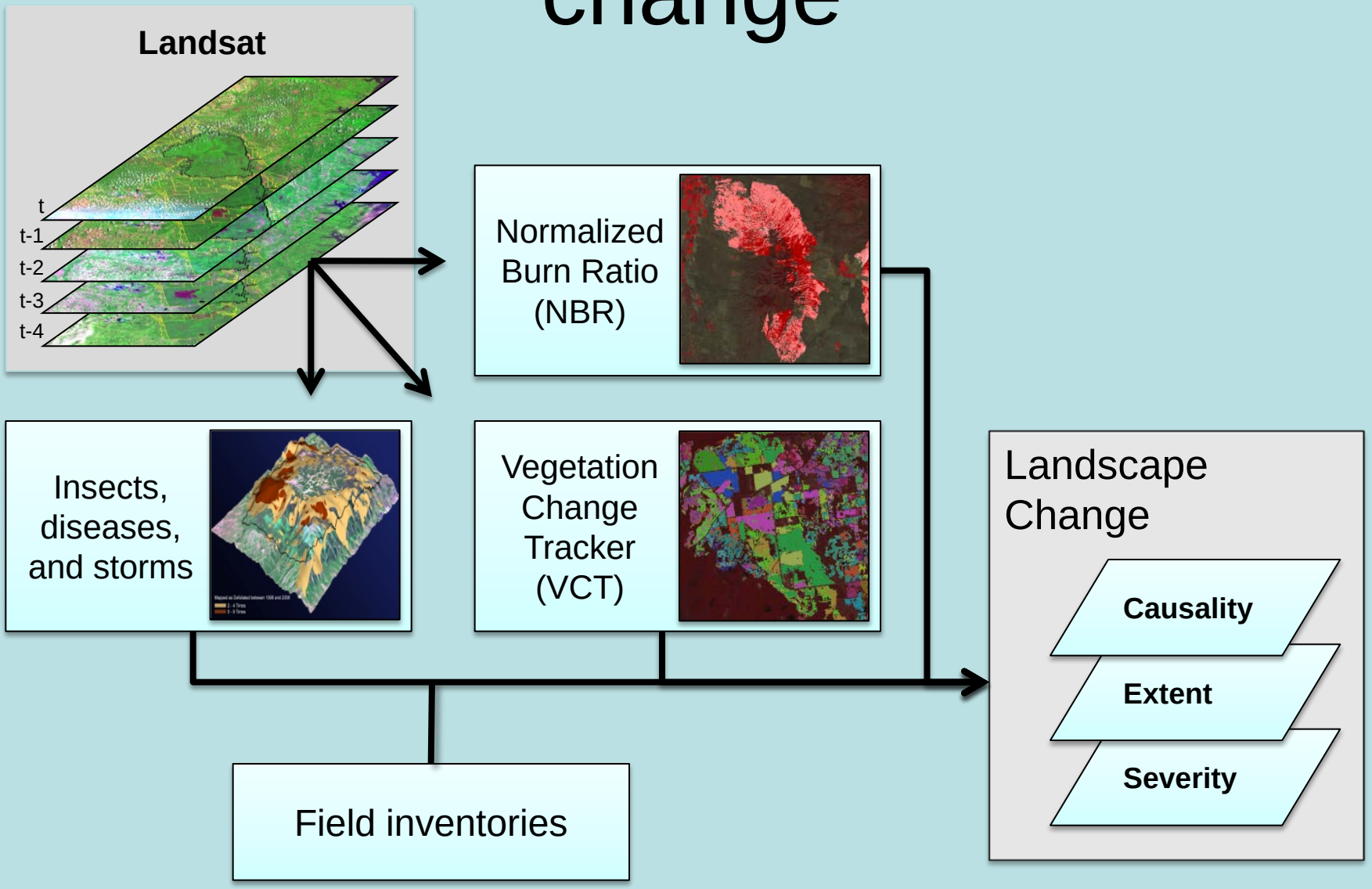
LANDFIRE Existing Vegetation



- Ca 500 ecological systems originally mapped
- National Vegetation Classification System hierarchy


Fire Behavior Fuel Models
LANDFIRE National
Legend
Grass Fuel Types
GR1
GR2
GR3
GR4
GR5
GR6
GR7
GR8
Grass-Shrub Fuel Types
GS1
GS2
GS3
GS4
Shrub Fuel Types
SH1
SH2
SH3
SH4
SH5
SH6
SH7
SH8
SH9
Timber Understory Fuel Types
TU1
TU2
TU3
TU5
Timber Litter Fuel Types
TL1
TL2
TL3
TL4
TL5
TL6
TL7
TL8
TL9
Slash-Blowdown Fuel Types
SB1
SB2
Non-Burnable Fuel Types
NB1
NB2
NB3
NB8
NB9

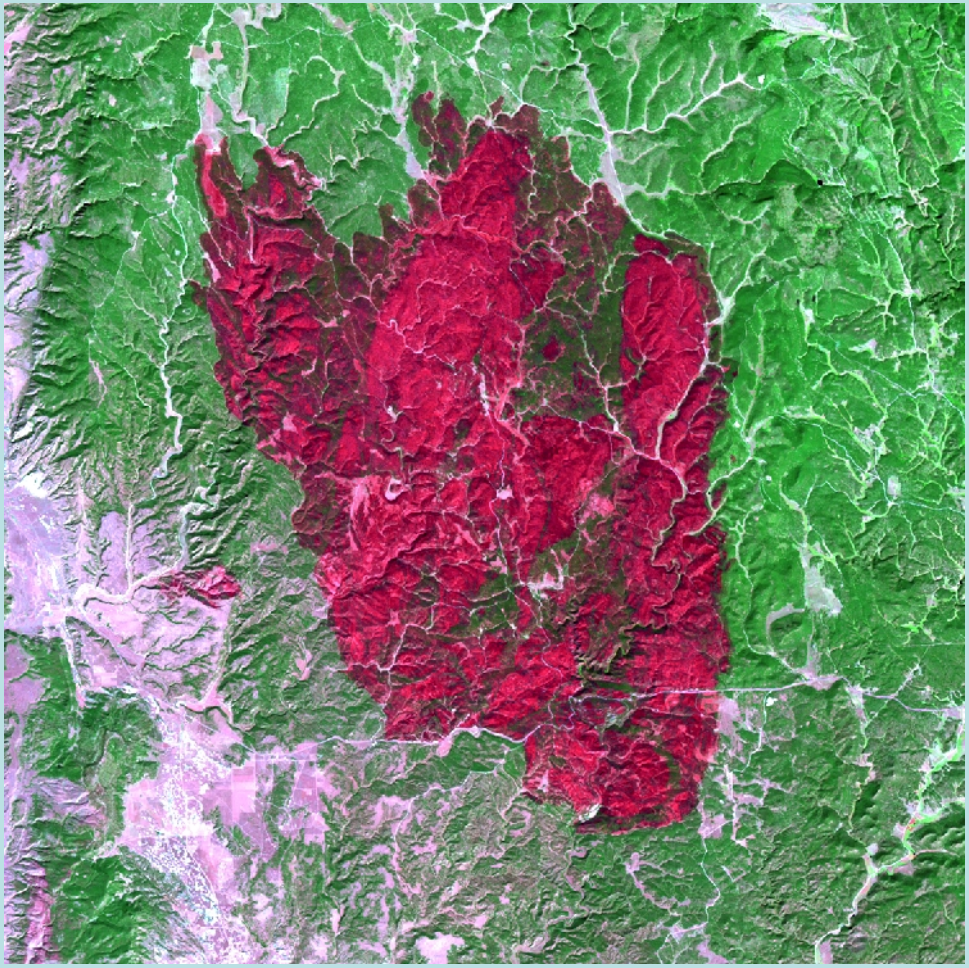
Characterizing landscape change



Monitoring Trends in Burn Severity

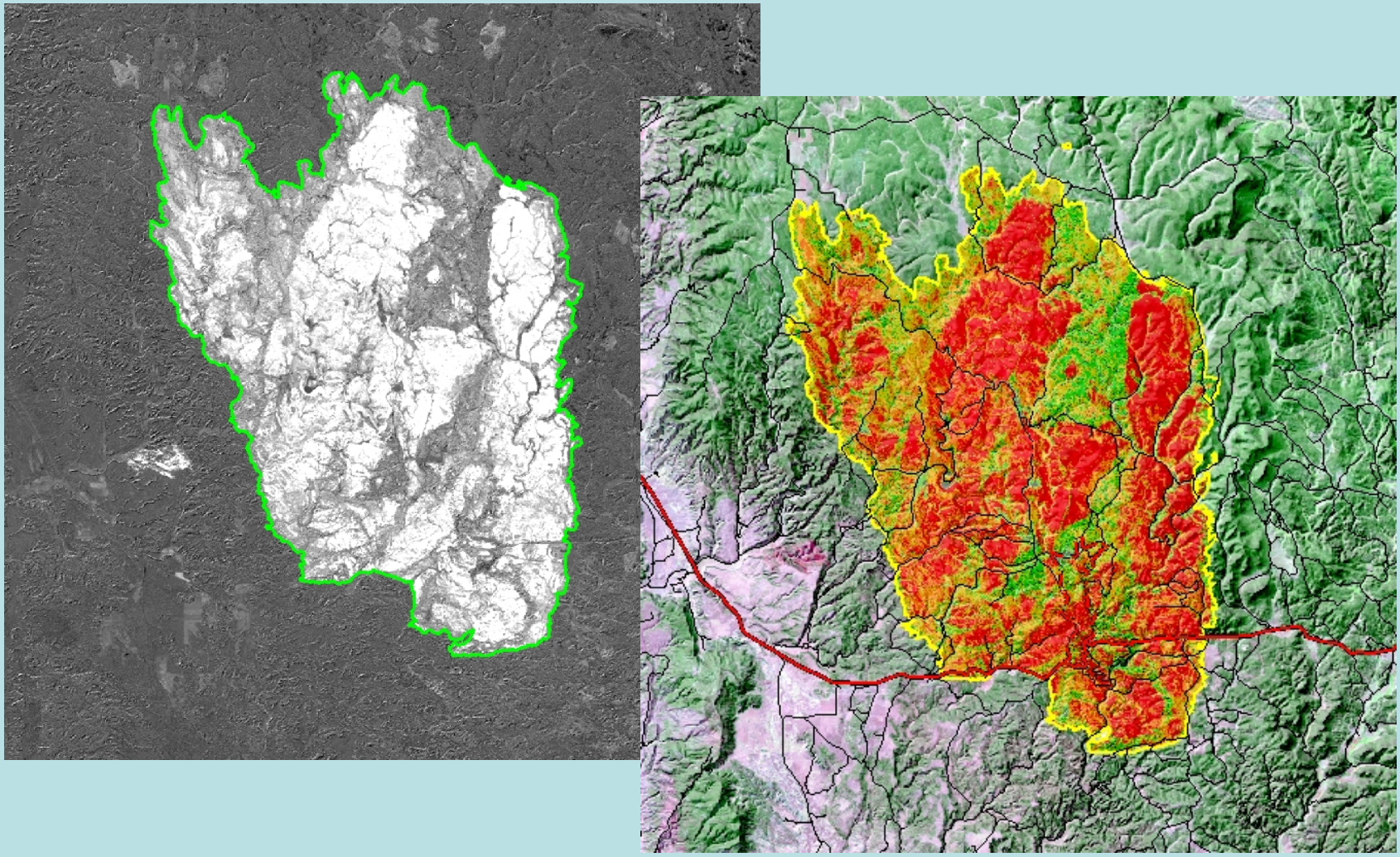
- Designed to consistently map the burn severity and perimeters of wildland fires across all lands of the US
  - From 1984 through 2010
  - 30 m resolution
  - Fires greater than 1000 acres mapped in western US
  - Fires greater than 500 acres mapped in the eastern US
  - Data available at http://www.mtbs.gov

Burn Mapping

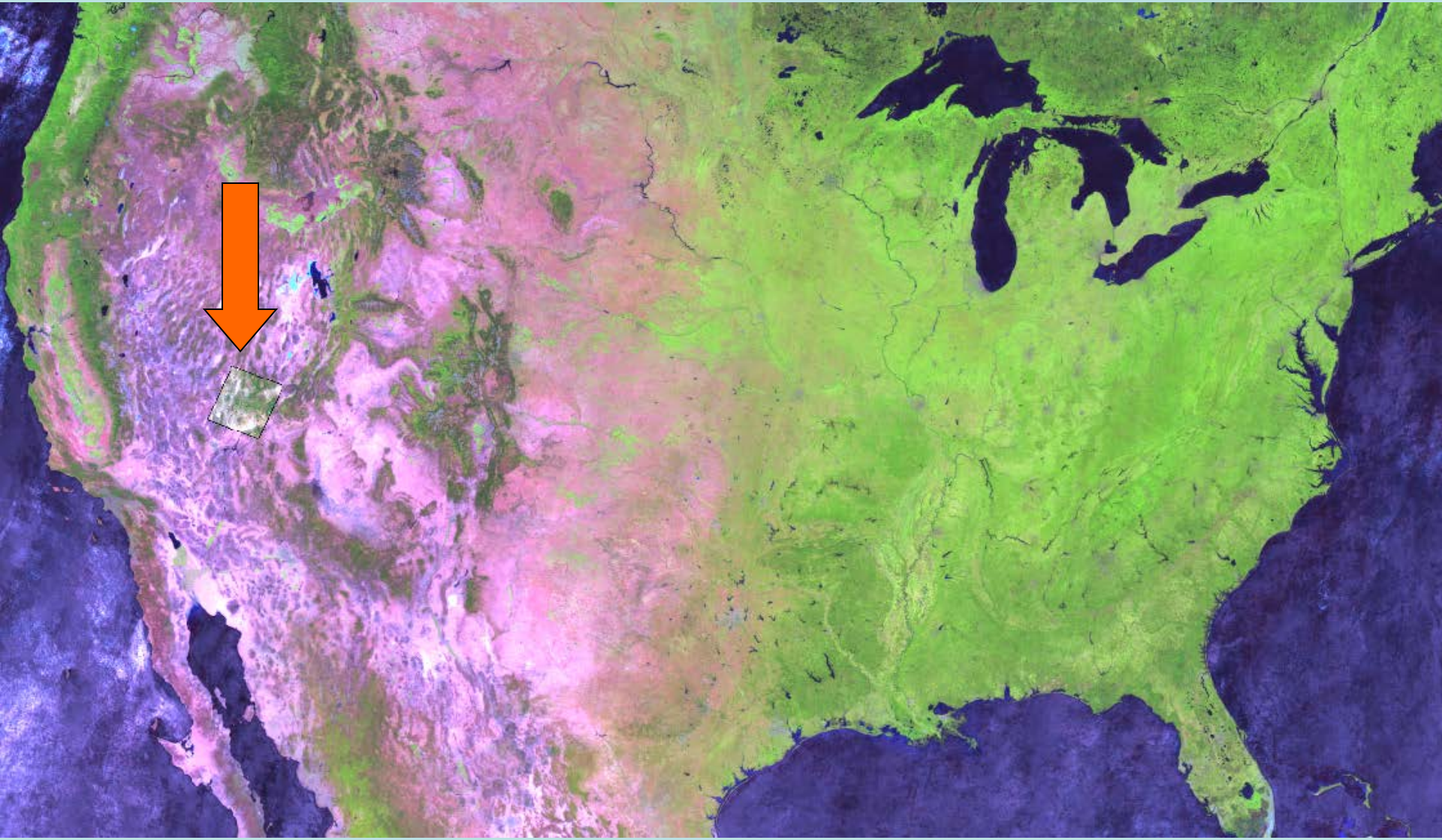


- Jasper fire:
- Start: August 24, 2000
- Controlled: Sept. 25, 2000
- 83,508 acres
- Cost to Contain $8.2M
- Timber Loss: 224 MBF
- Cause: Arson

Burn Mapping



Path 39 Row 34



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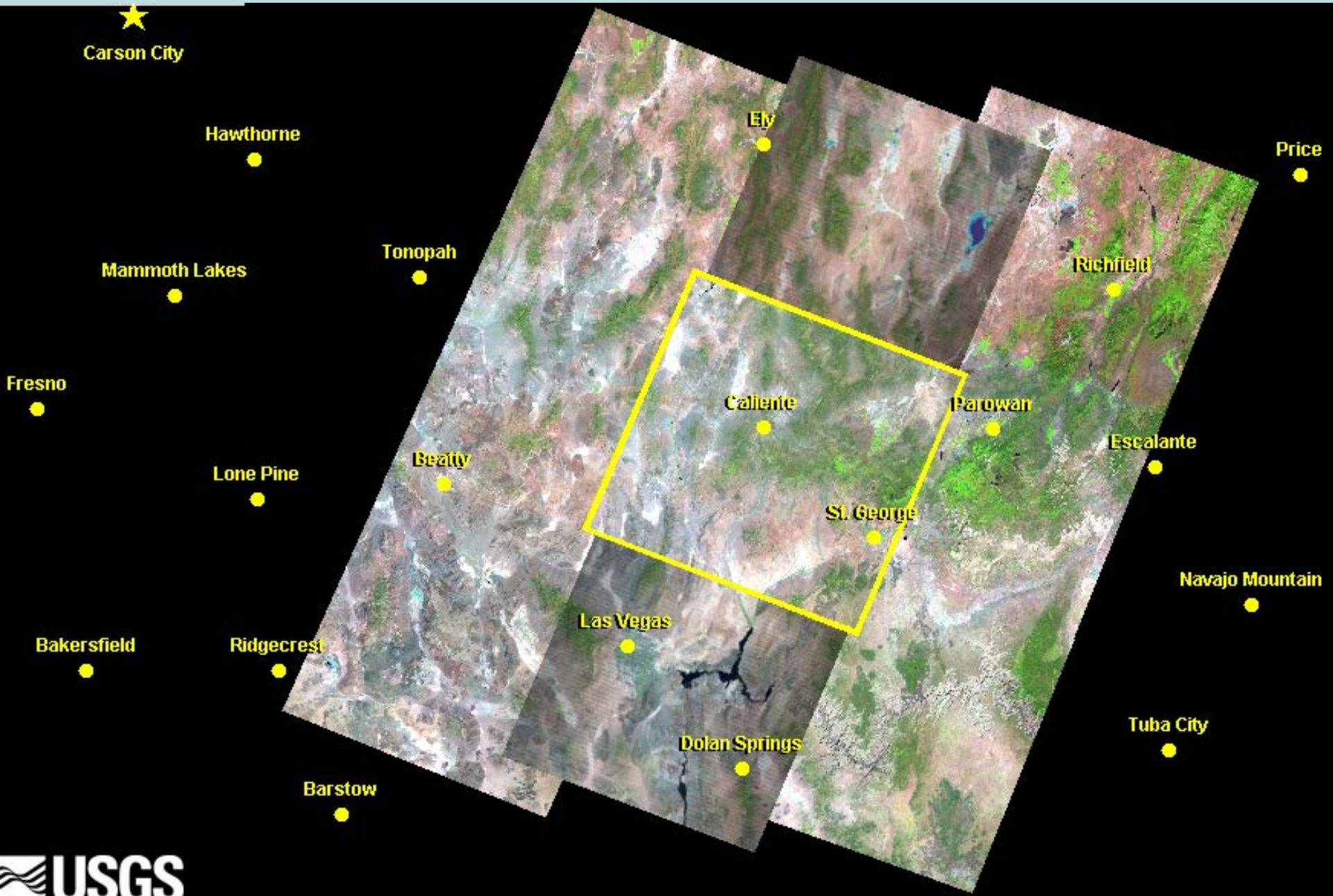
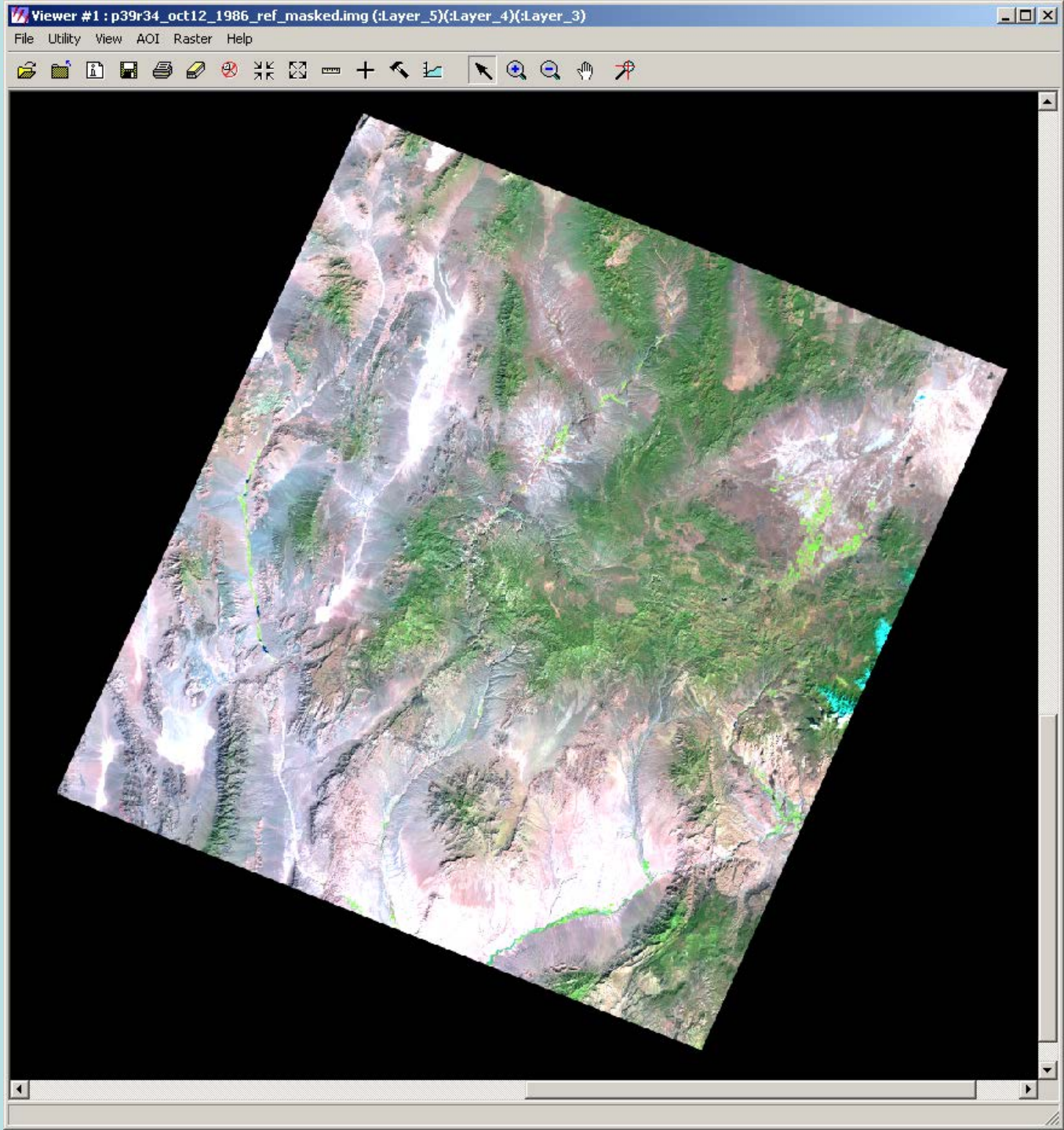
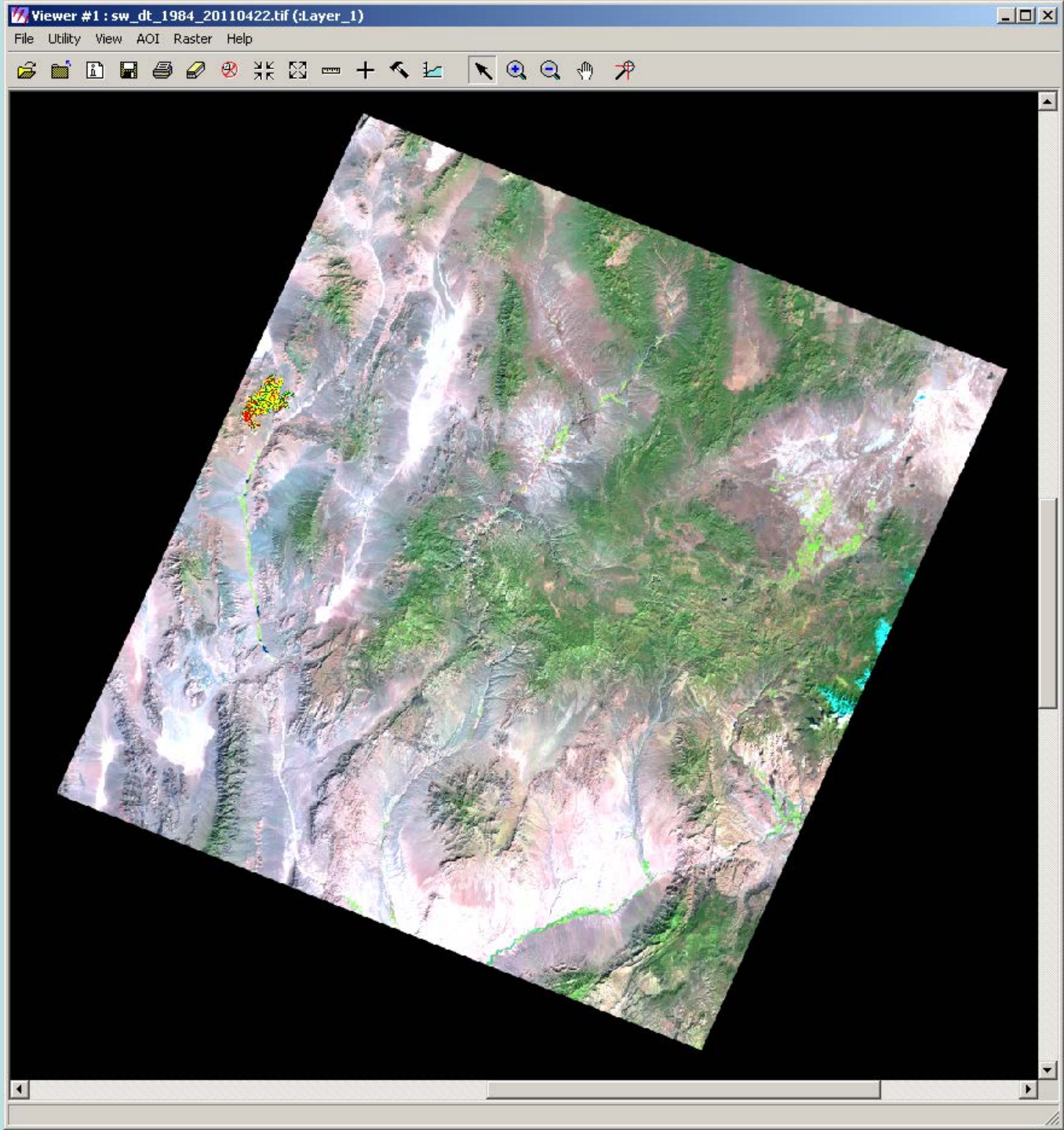


Path 39 Row 34



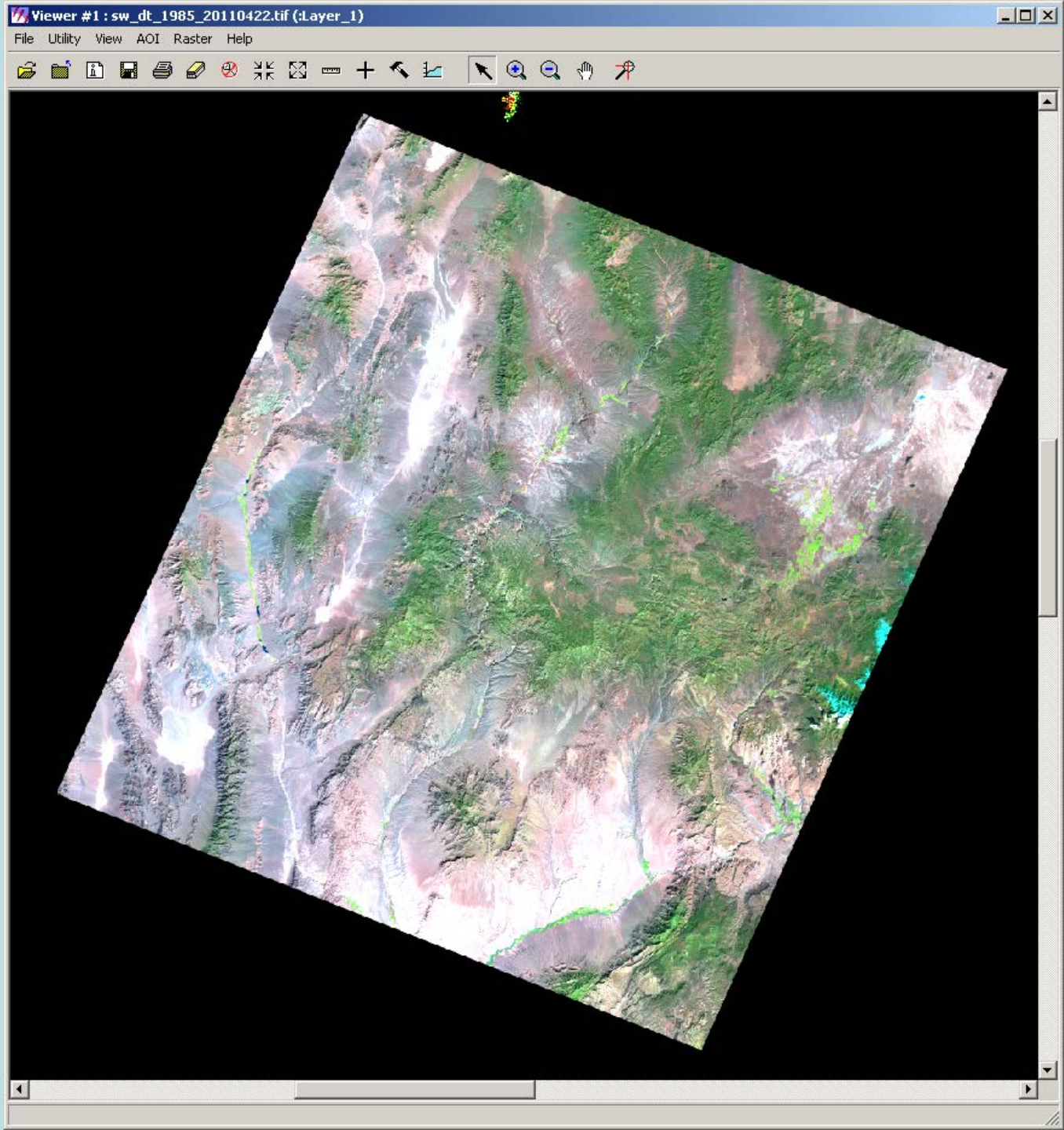
Path 39 Row 34
MTBS Fire Data 1984



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

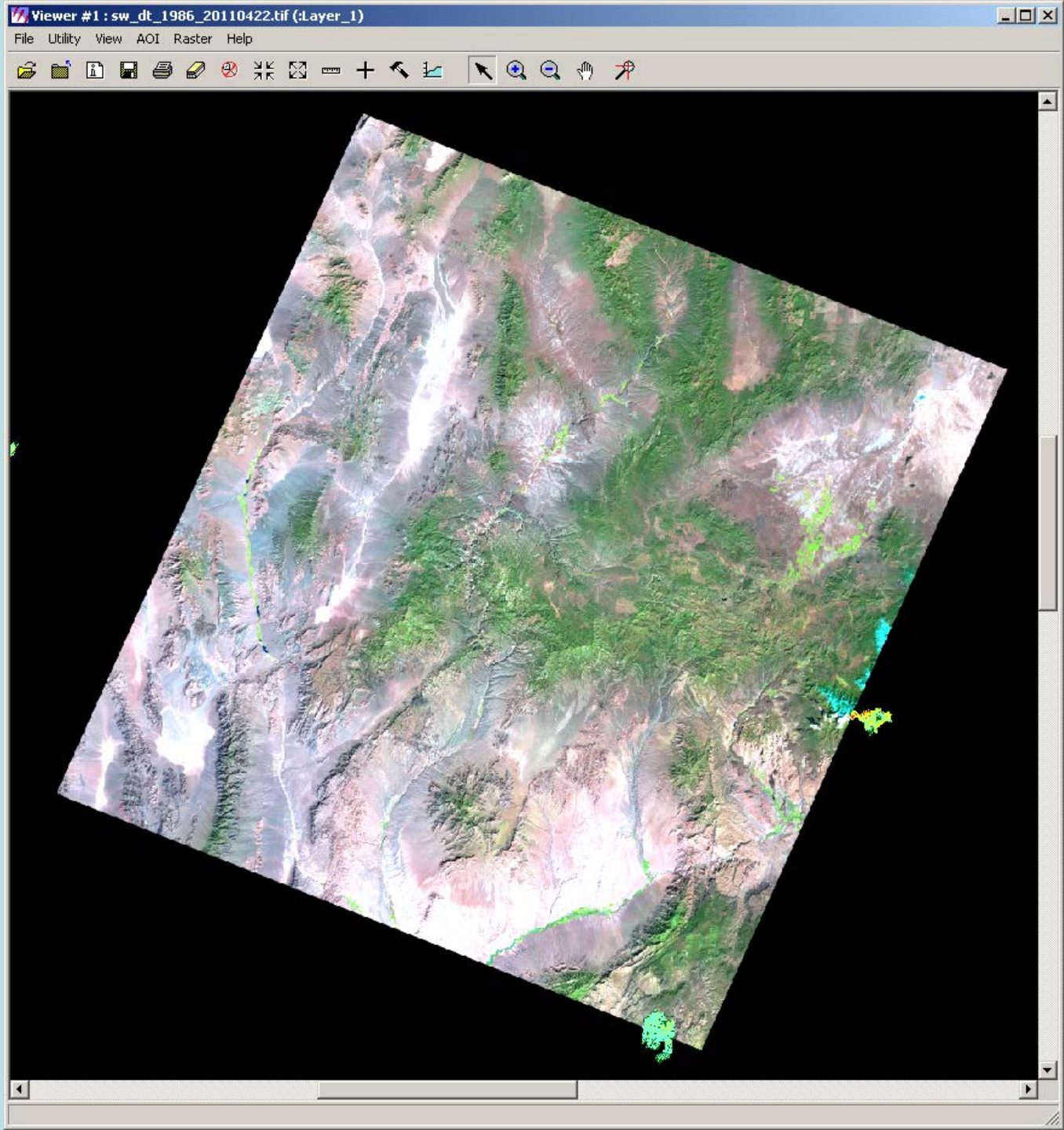
Path 39 Row 34
MTBS Fire Data 1985



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

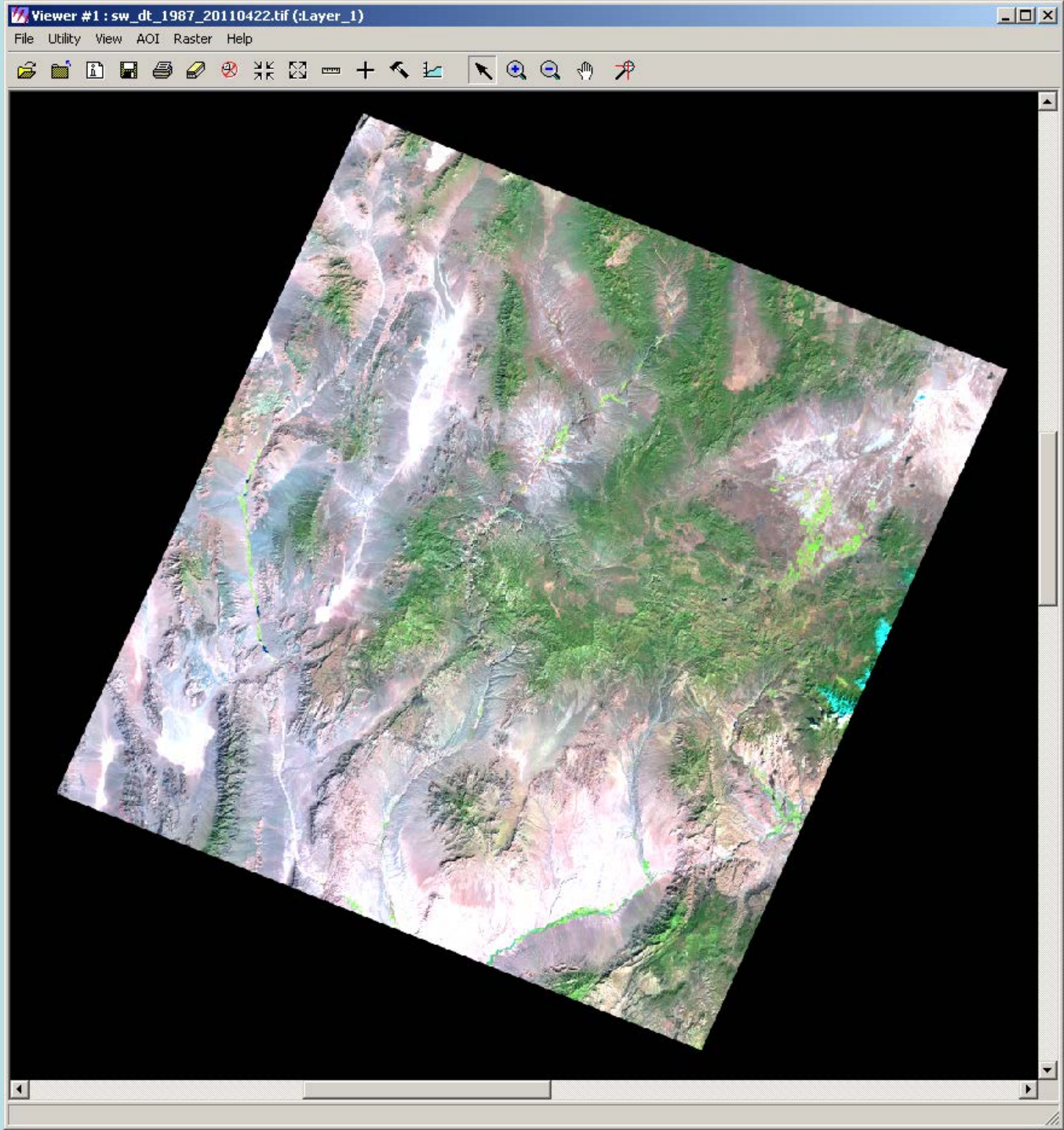
Path 39 Row 34
MTBS Fire Data 1986



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

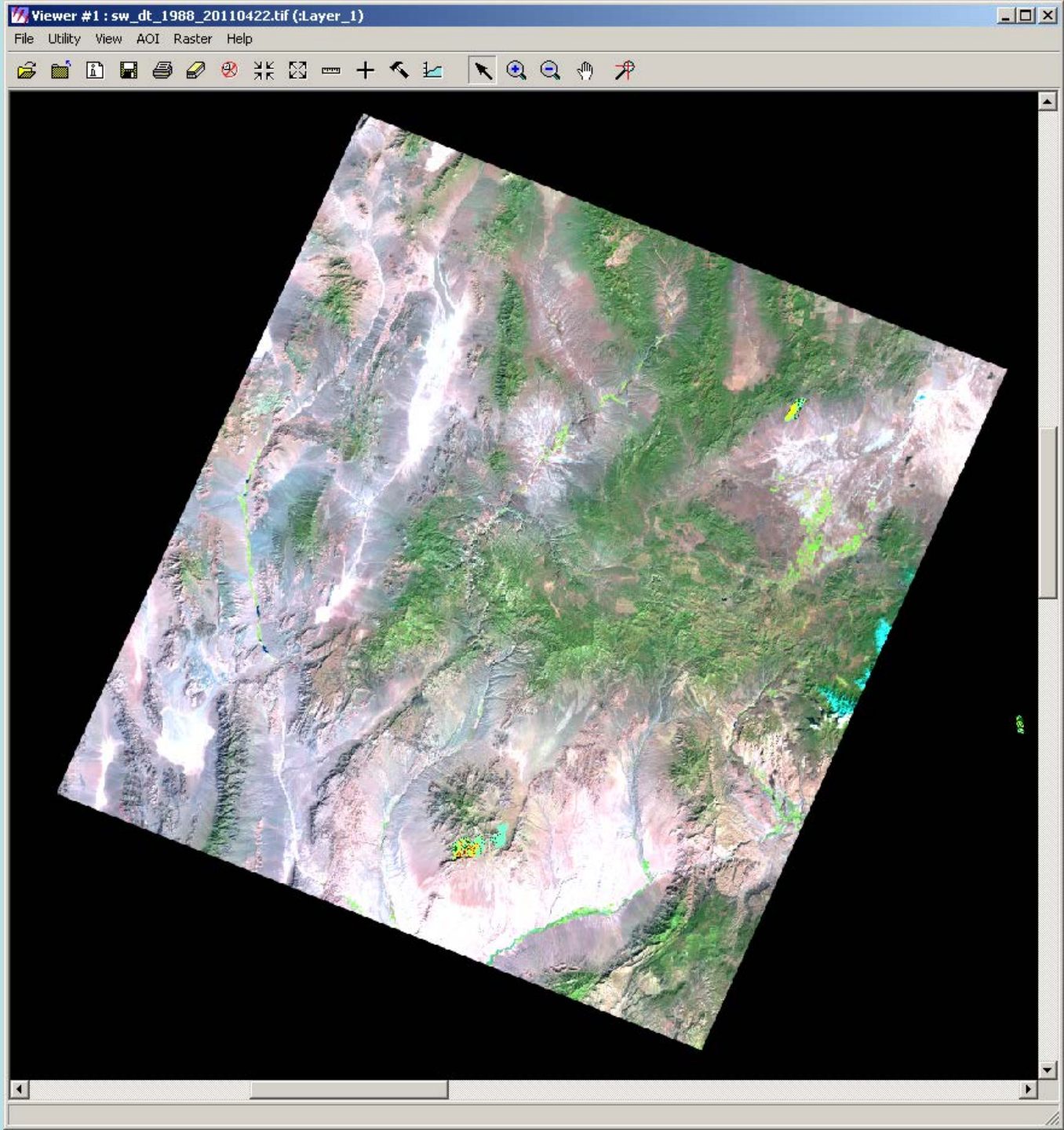
Path 39 Row 34
MTBS Fire Data 1987



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

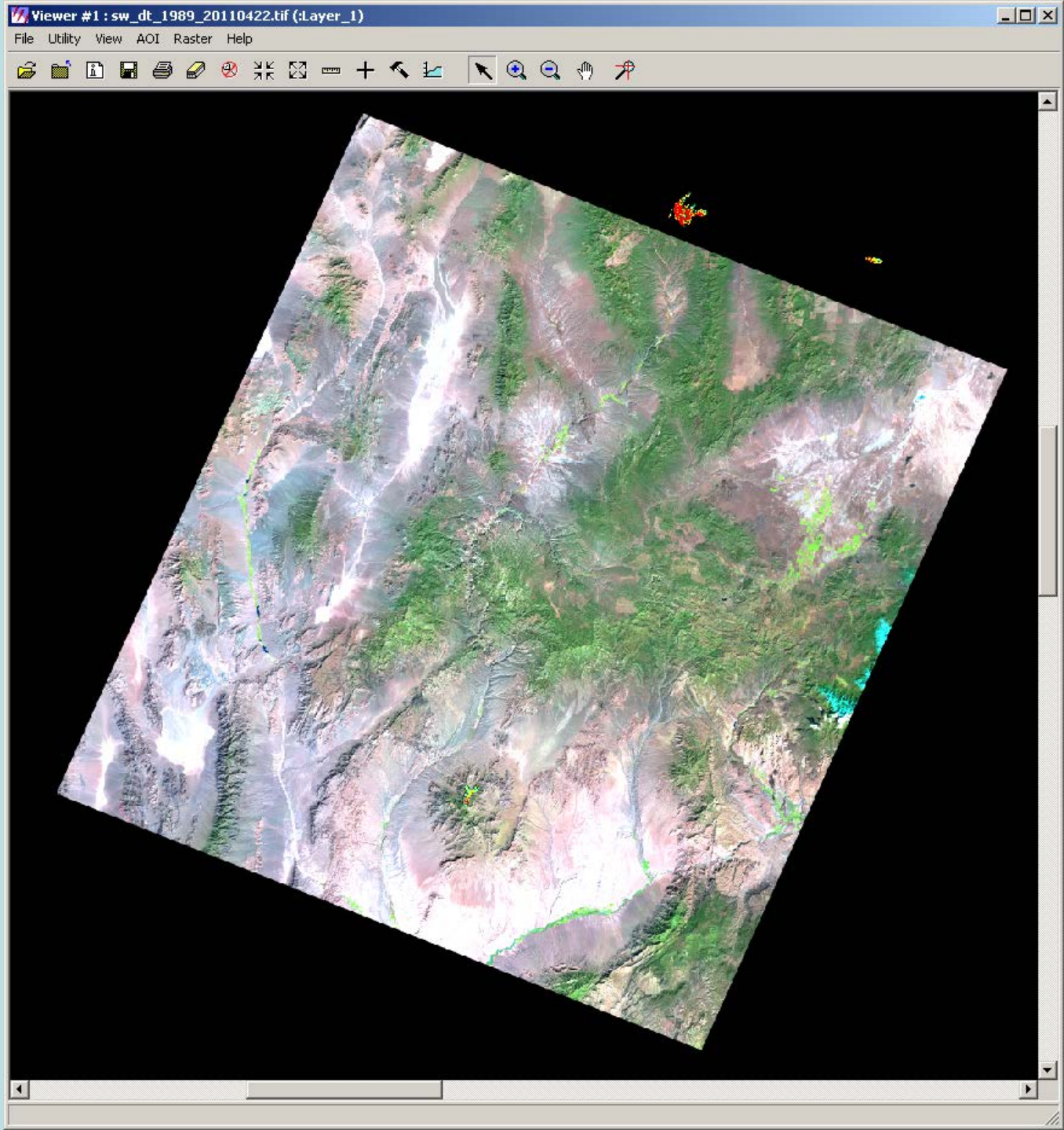
Path 39 Row 34
MTBS Fire Data 1988



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

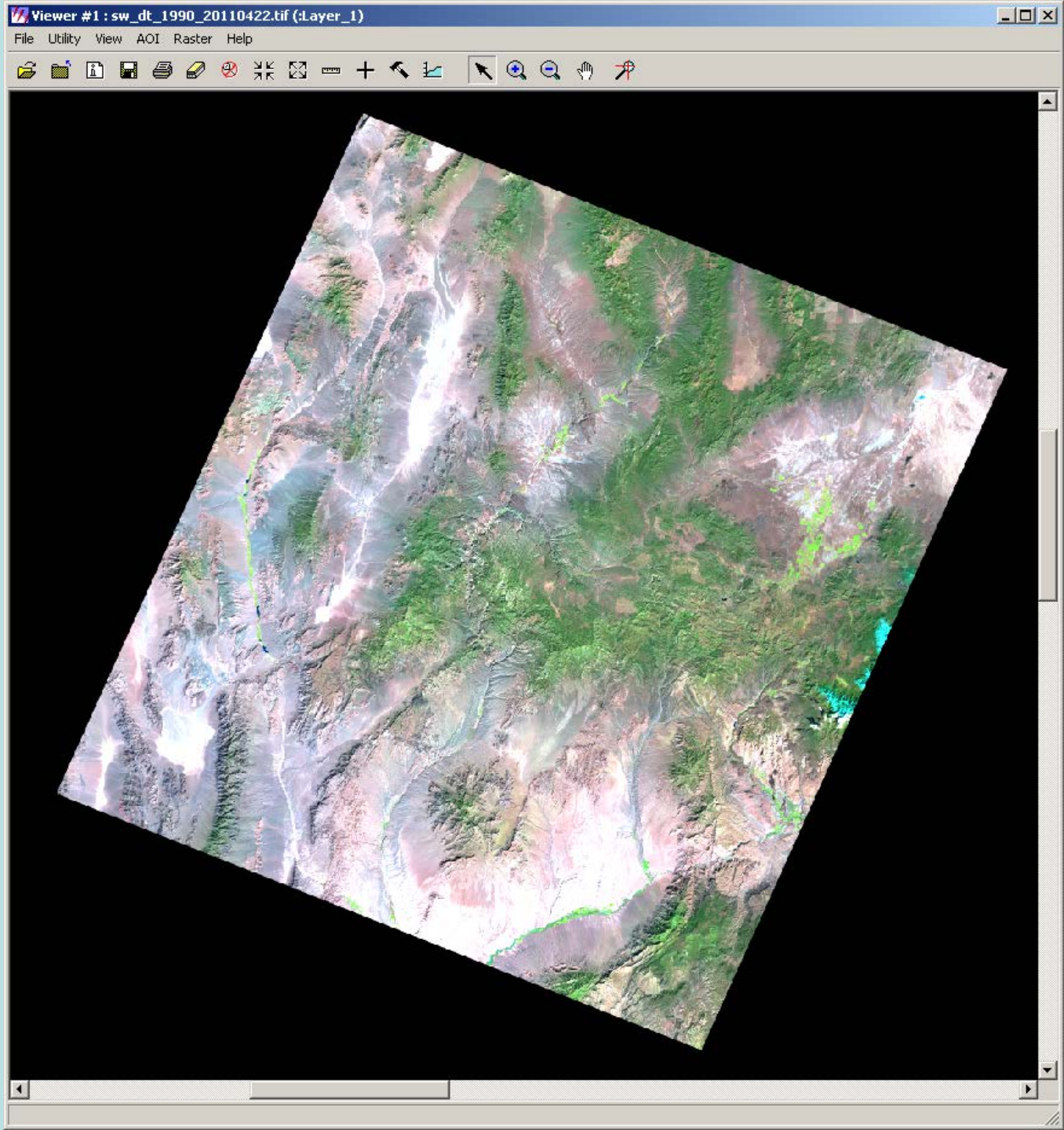
Path 39 Row 34
MTBS Fire Data 1989



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

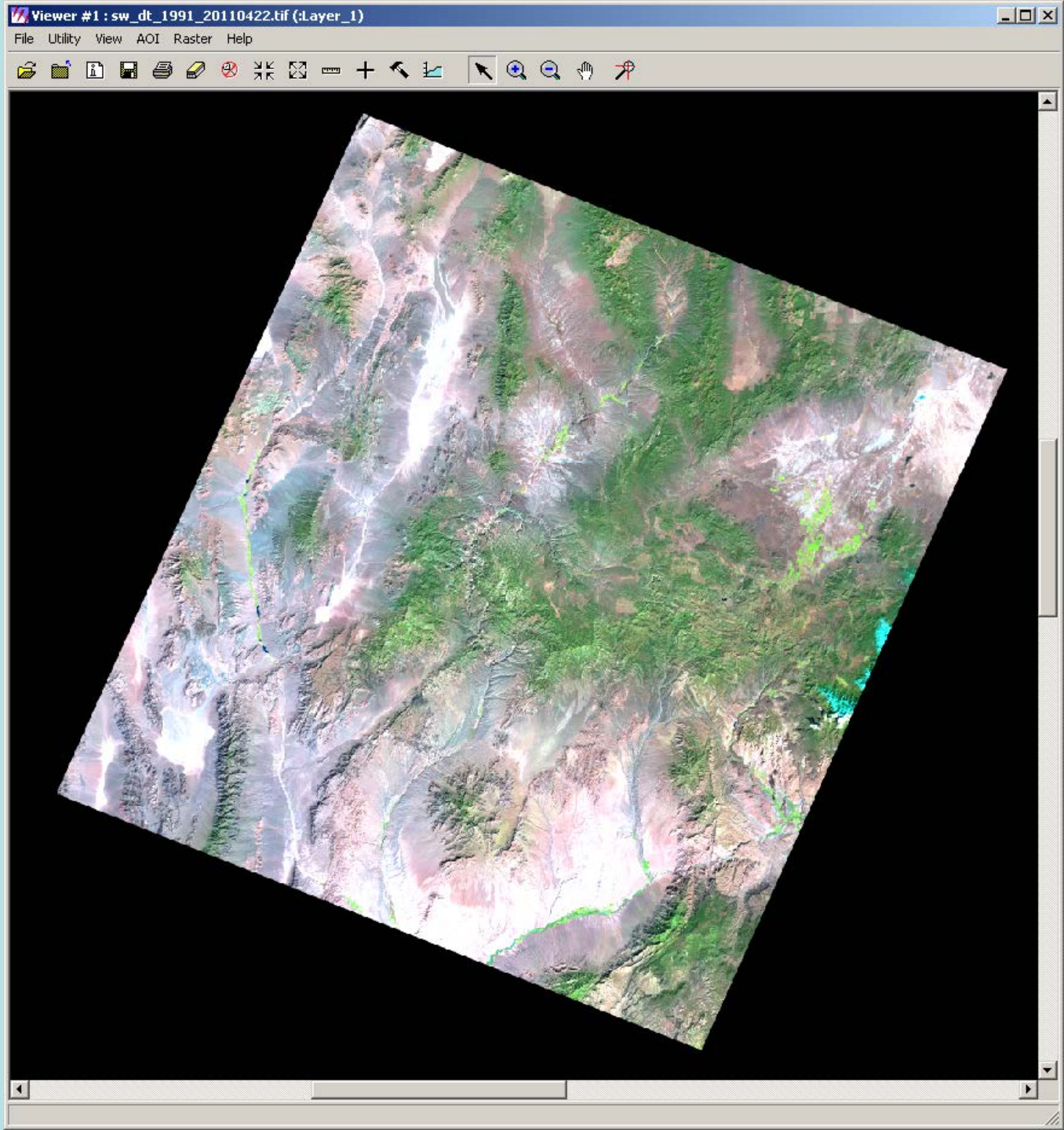
Path 39 Row 34
MTBS Fire Data 1990



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

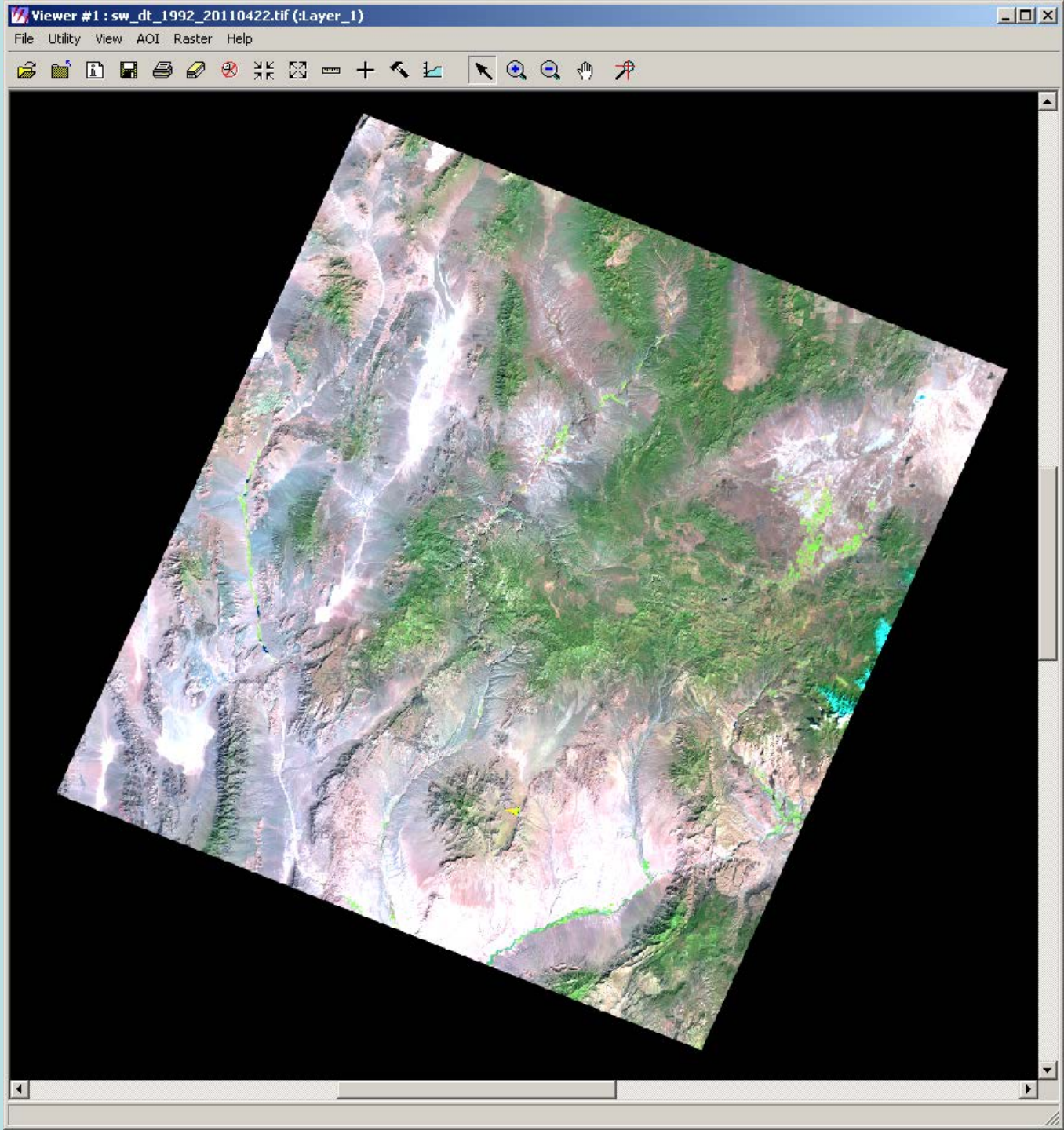
Path 39 Row 34
MTBS Fire Data 1991



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

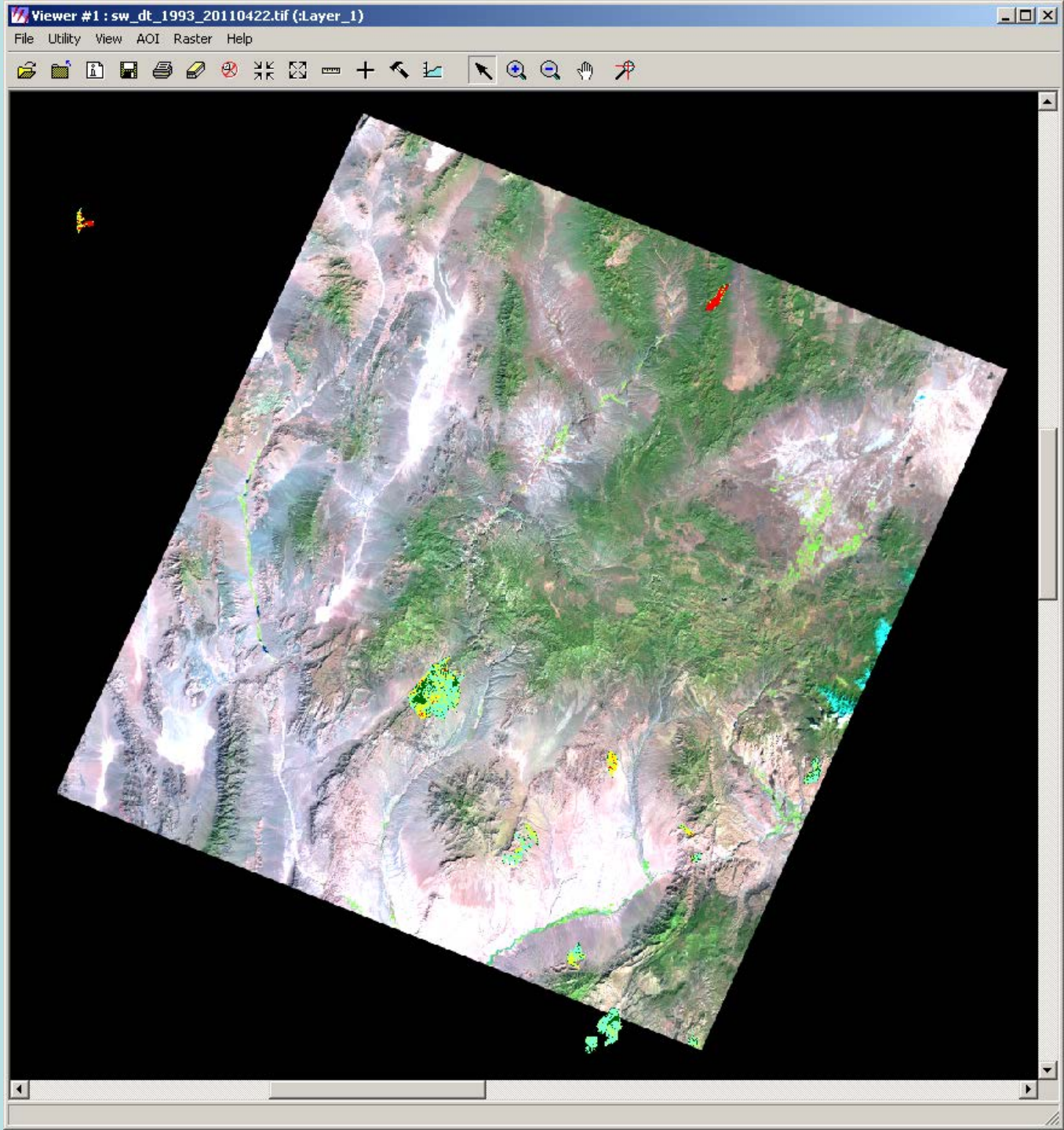
Path 39 Row 34
MTBS Fire Data 1992



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

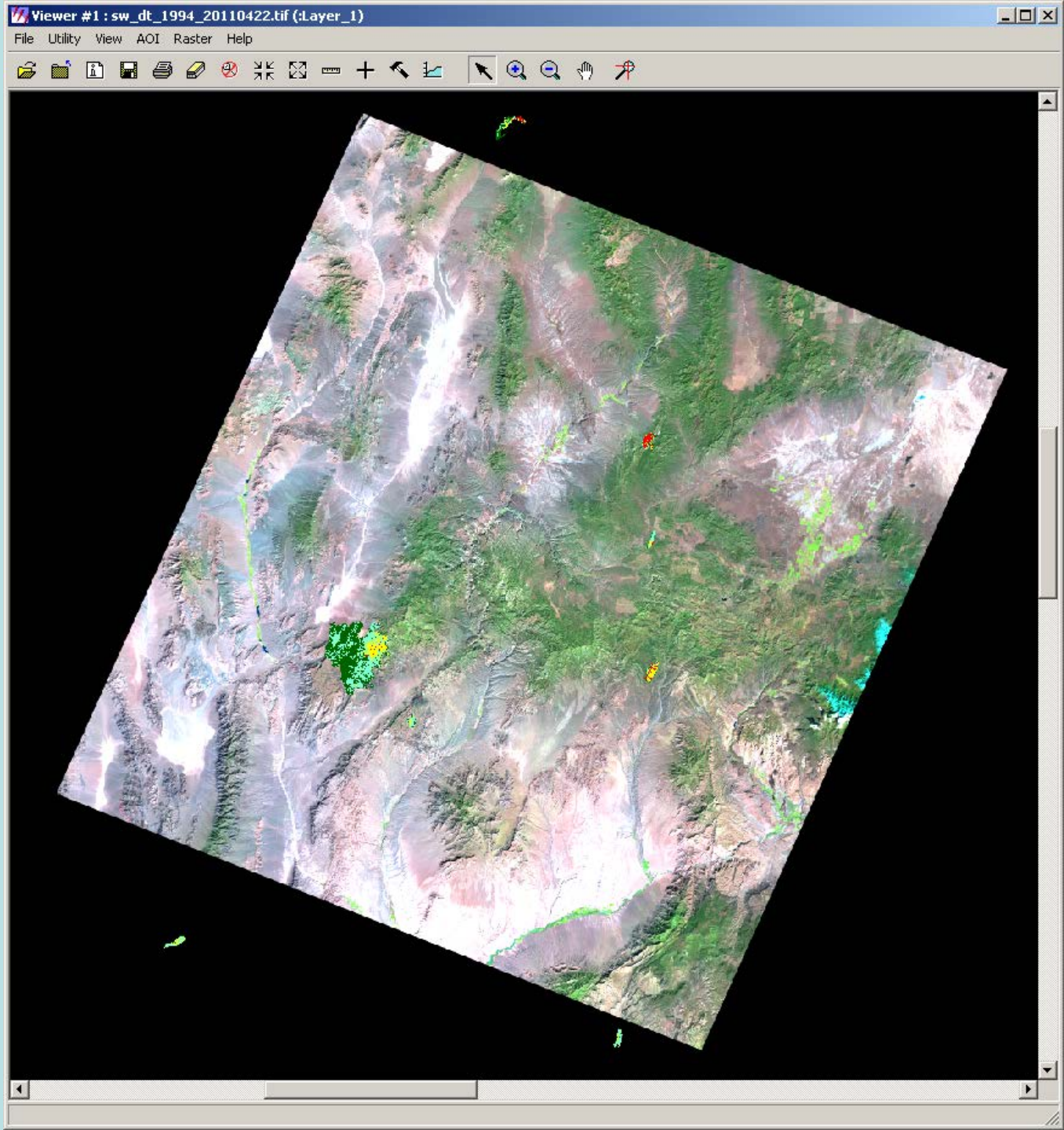
Path 39 Row 34
MTBS Fire Data 1993



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

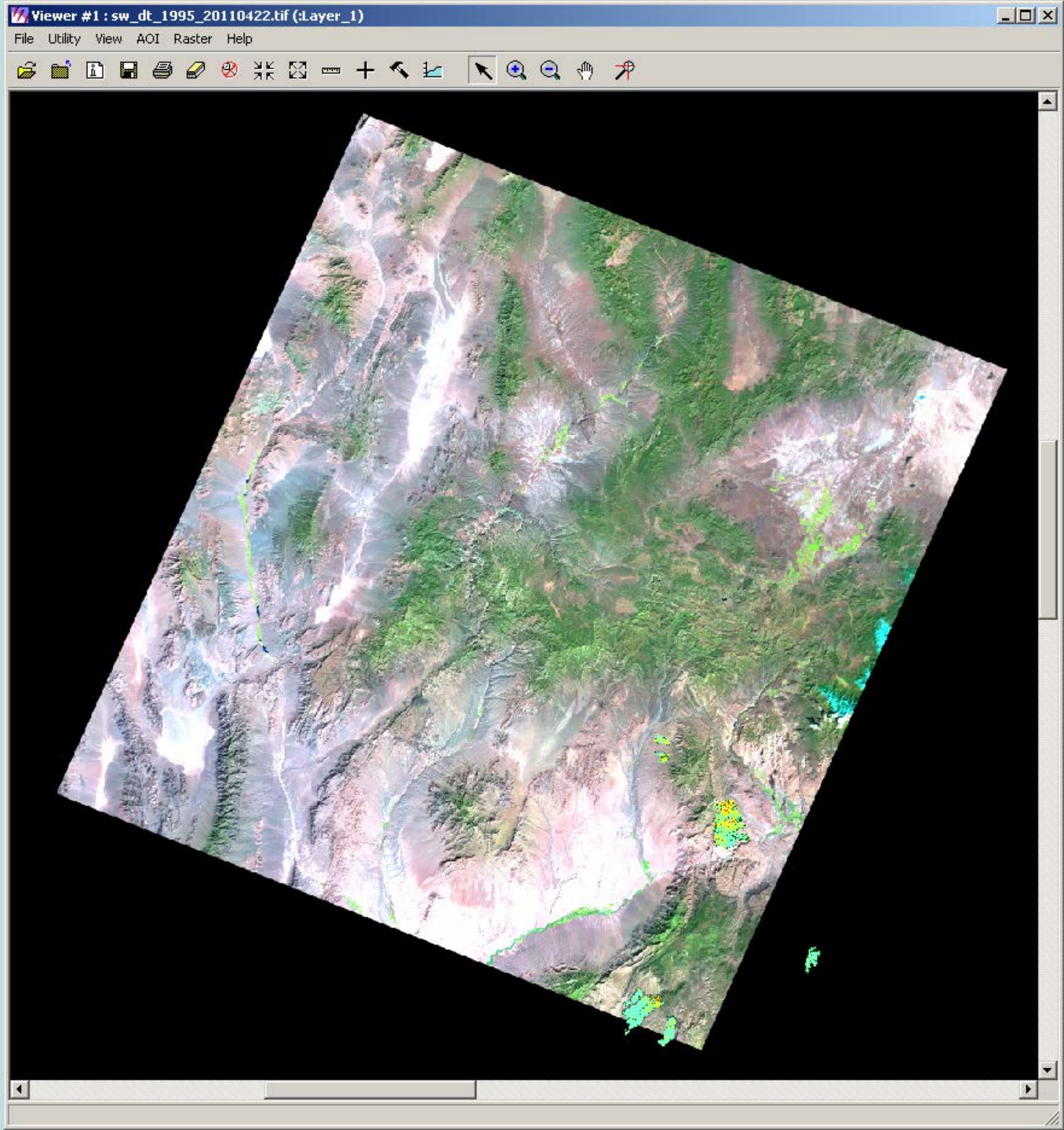
Path 39 Row 34
MTBS Fire Data 1994



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

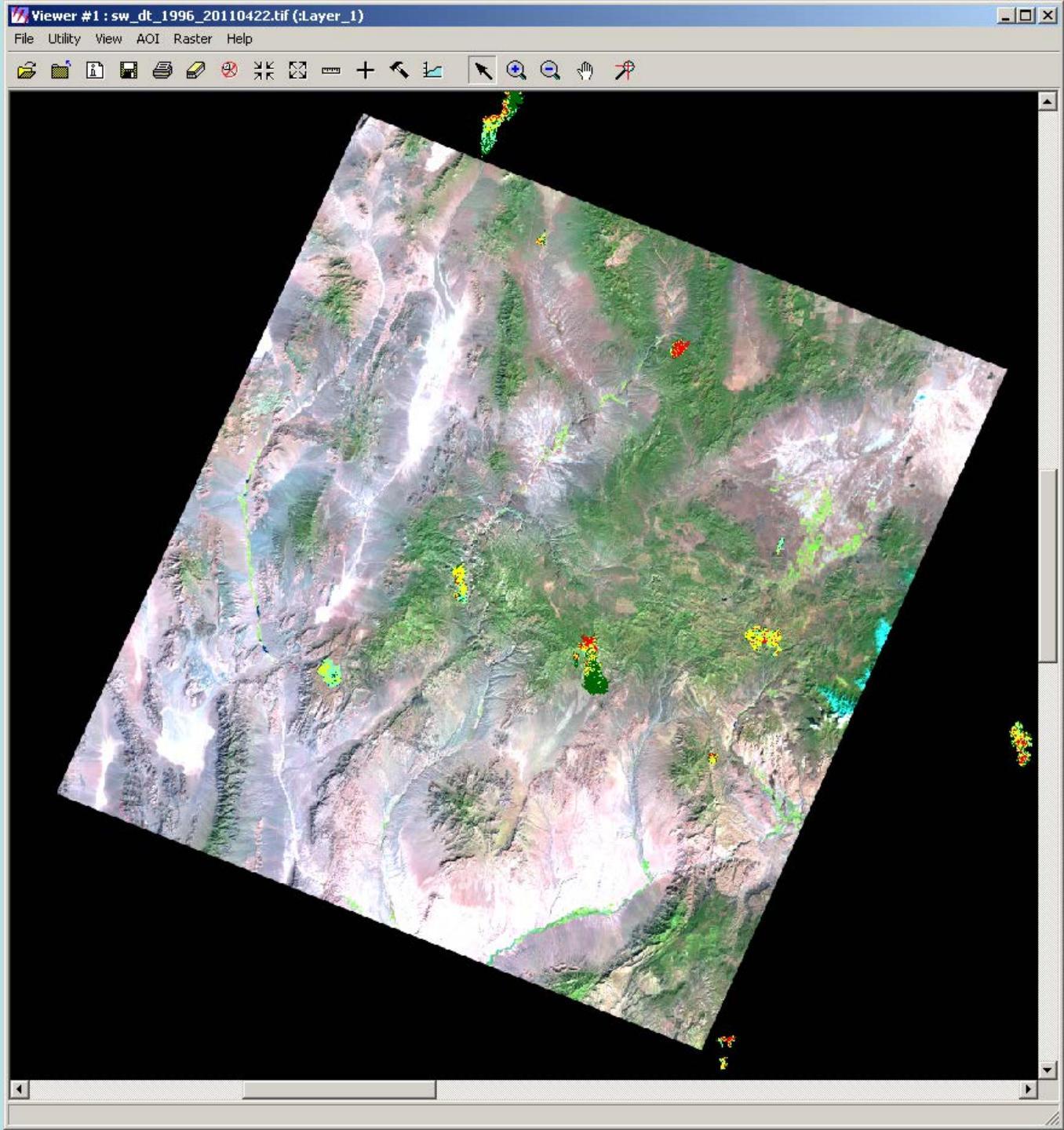
Path 39 Row 34
MTBS Fire Data 1995



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

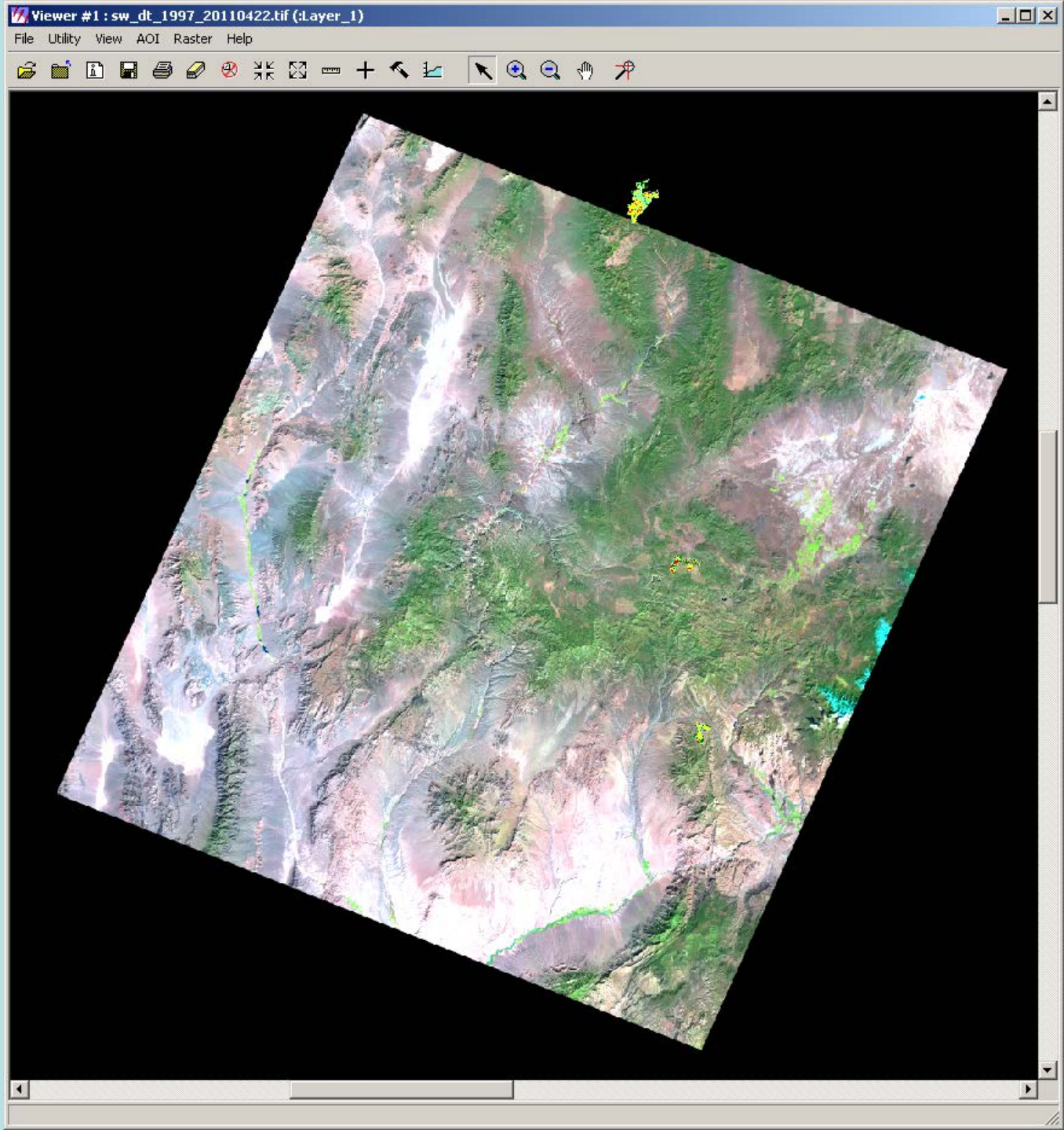
Path 39 Row 34
MTBS Fire Data 1996



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

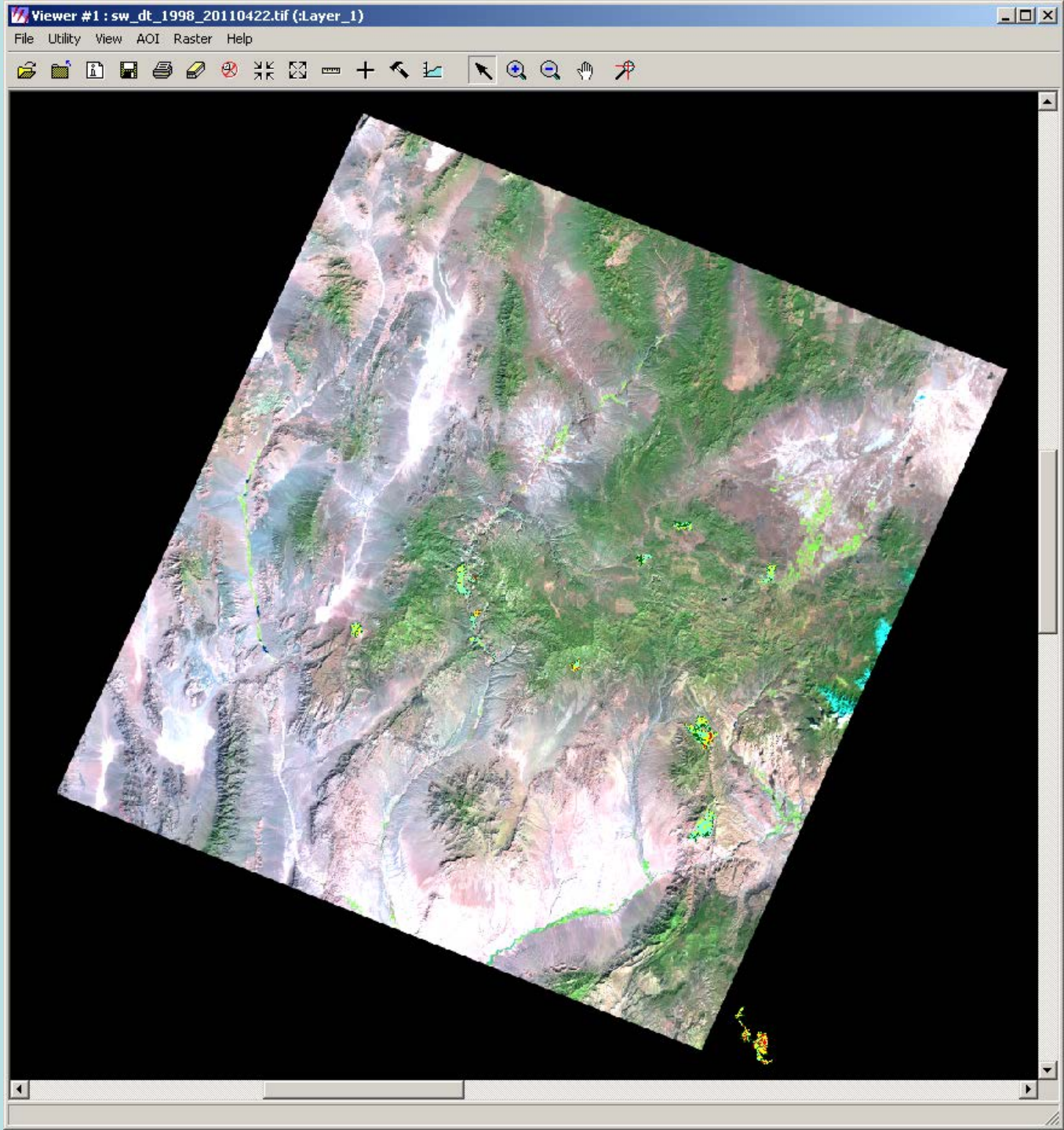
Path 39 Row 34
MTBS Fire Data 1997



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

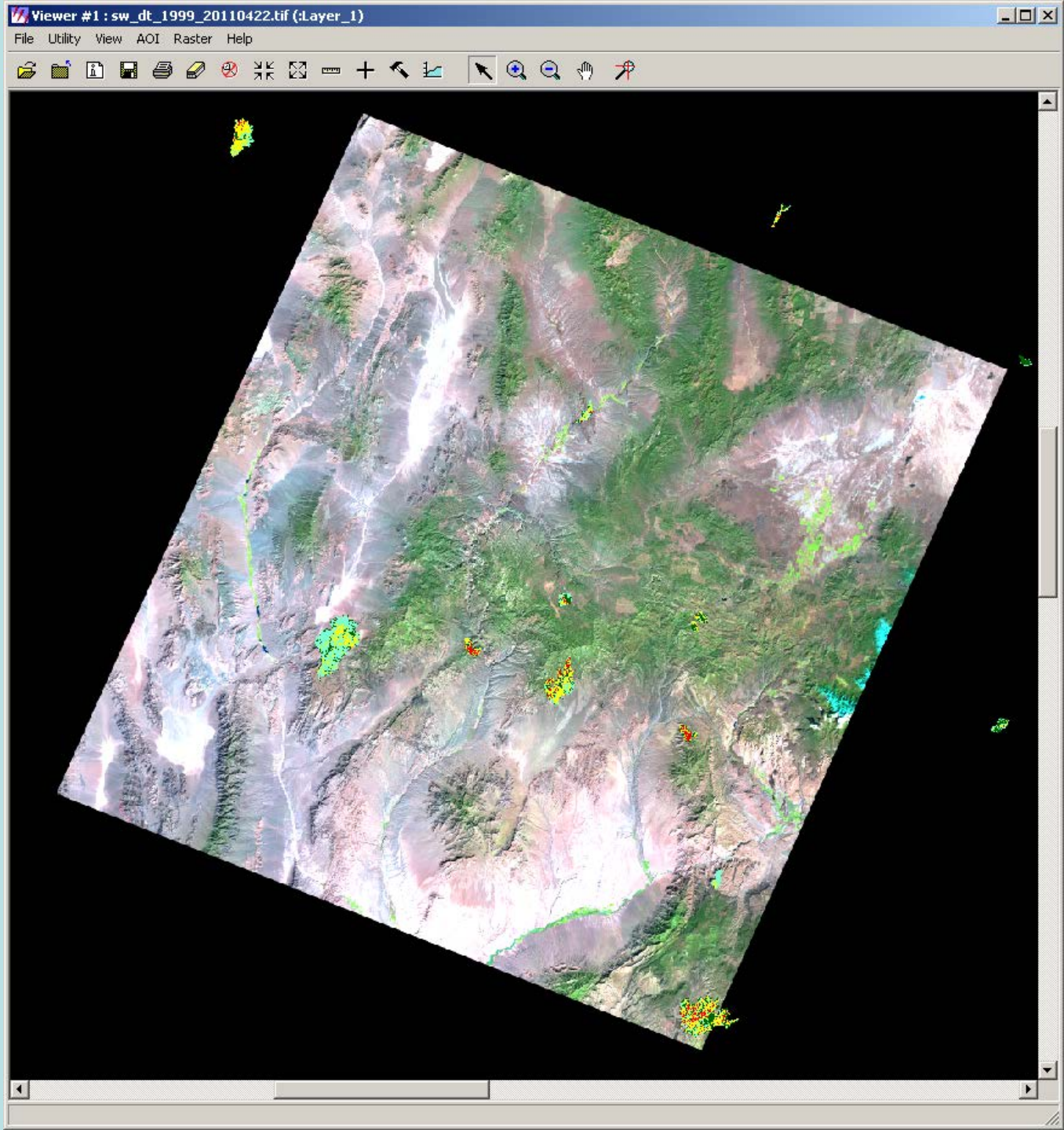
Path 39 Row 34
MTBS Fire Data 1998



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

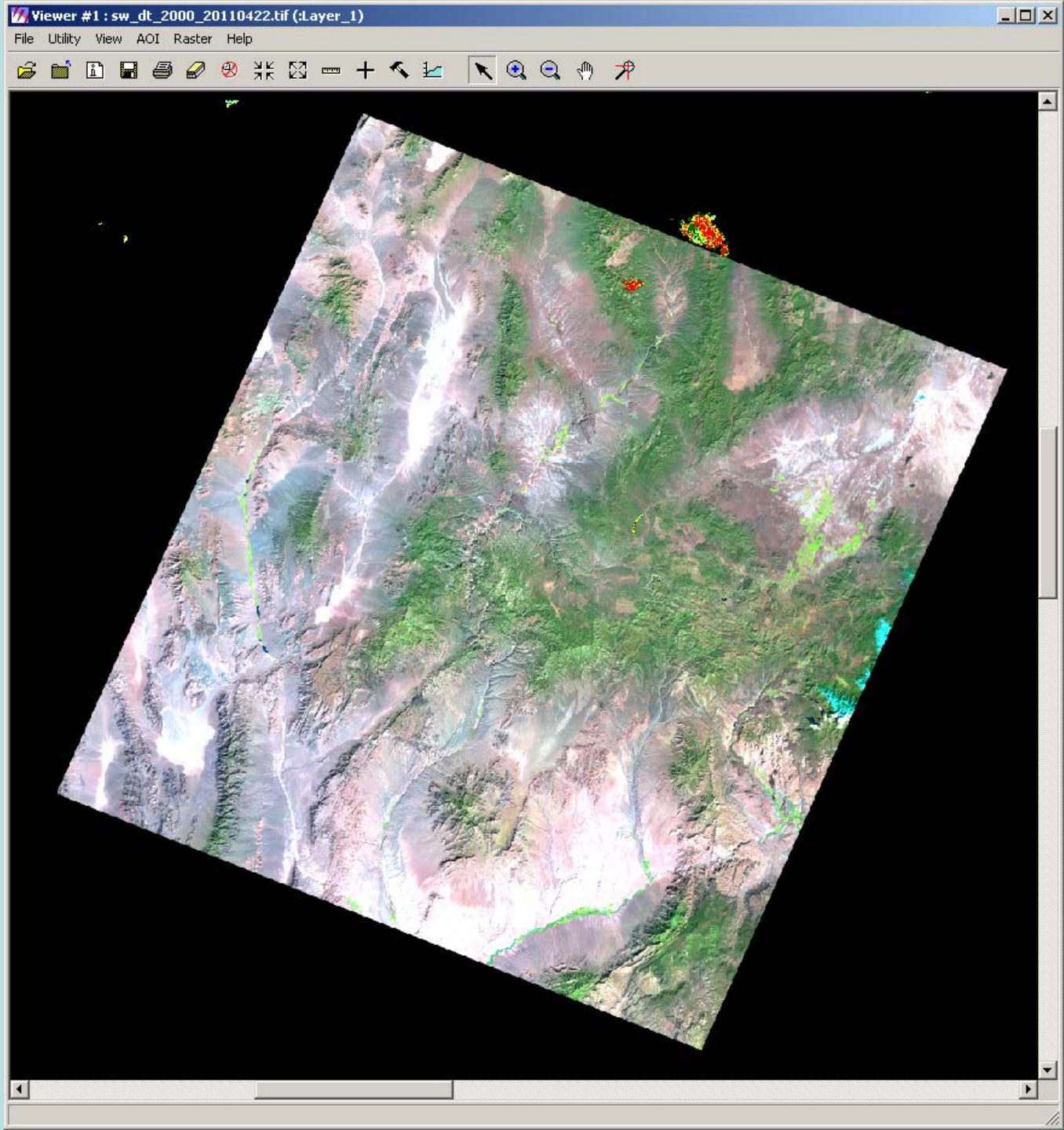
Path 39 Row 34
MTBS Fire Data 1999



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

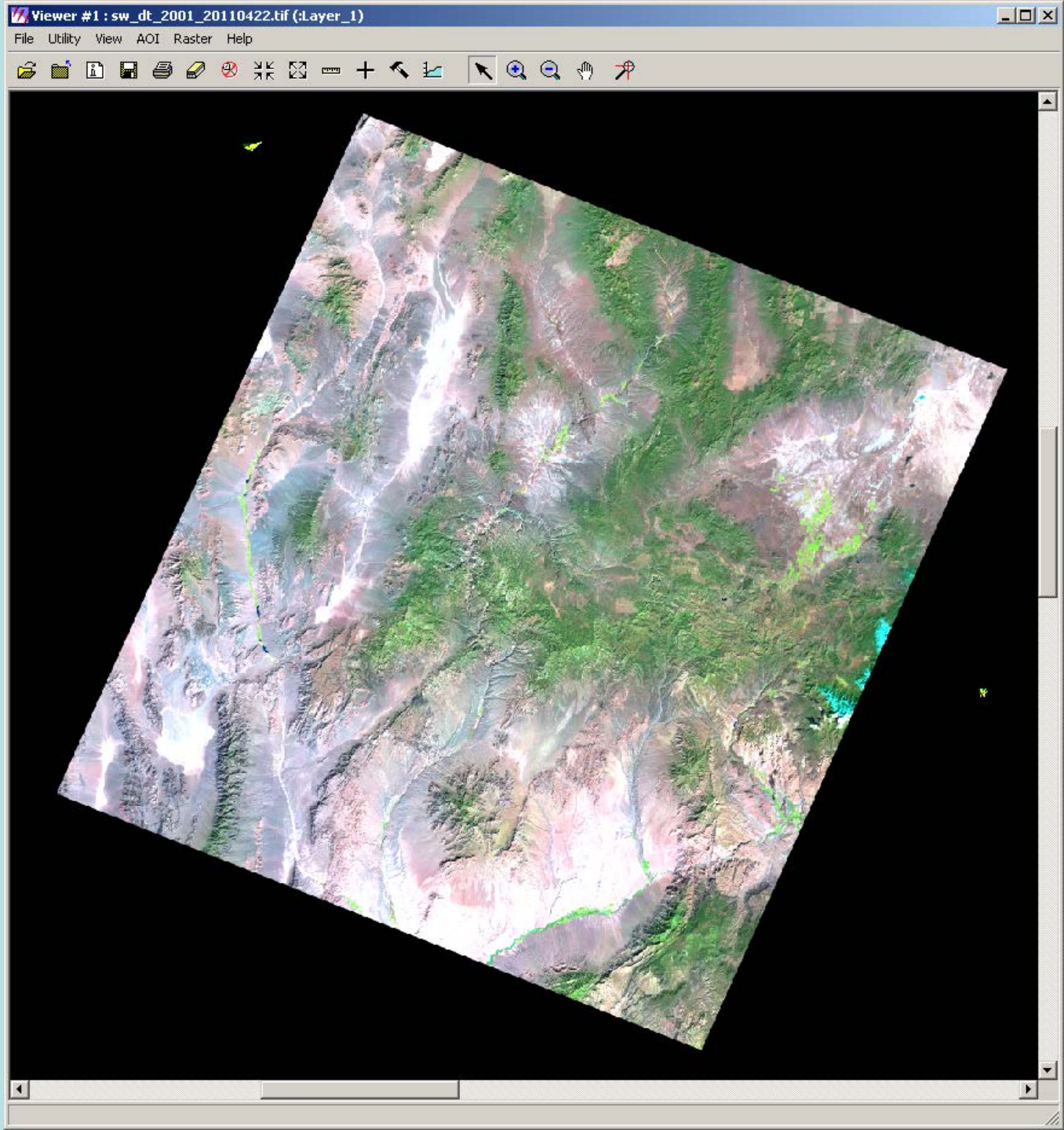
Path 39 Row 34
MTBS Fire Data 2000



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

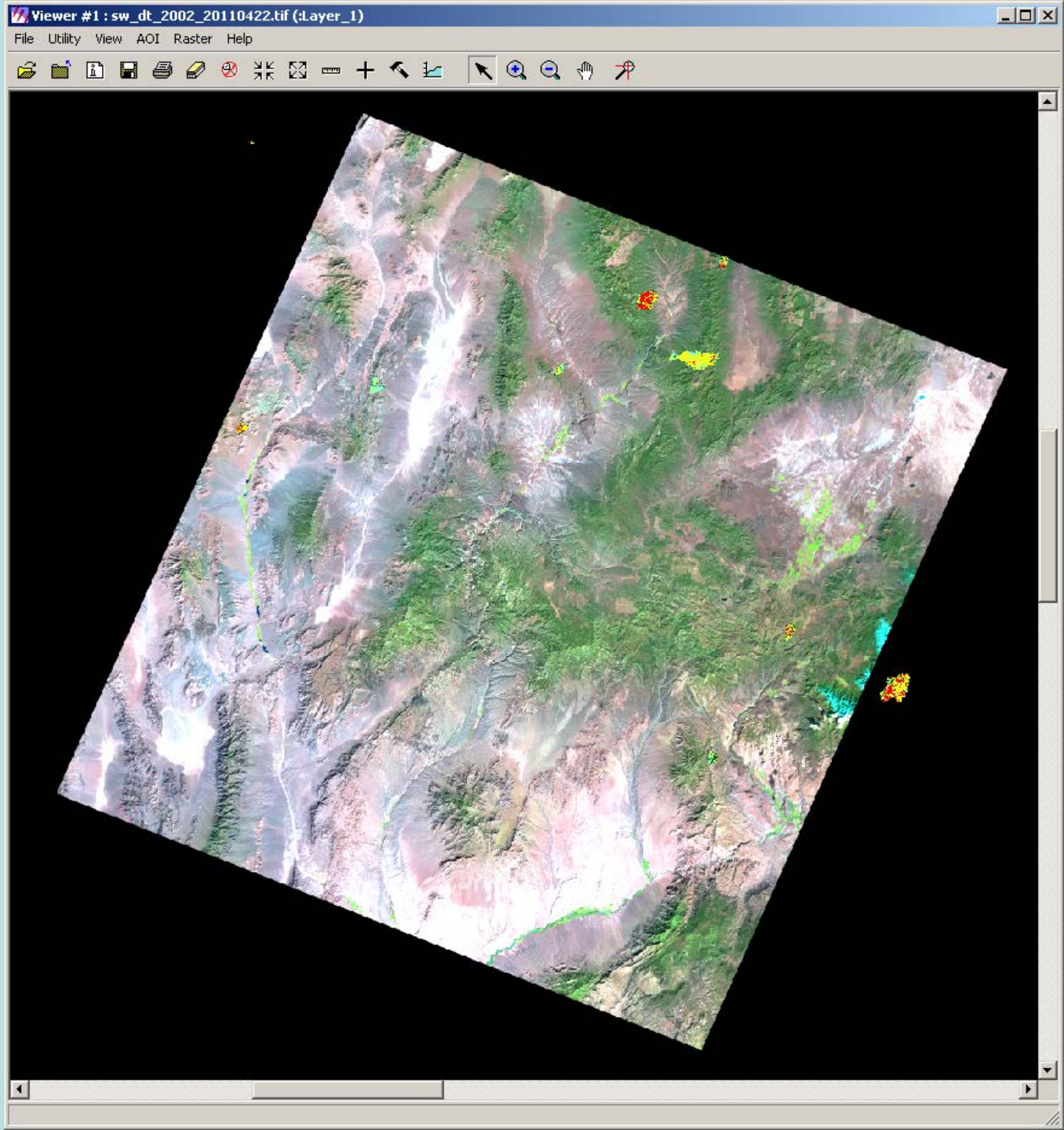
Path 39 Row 34
MTBS Fire Data 2001



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

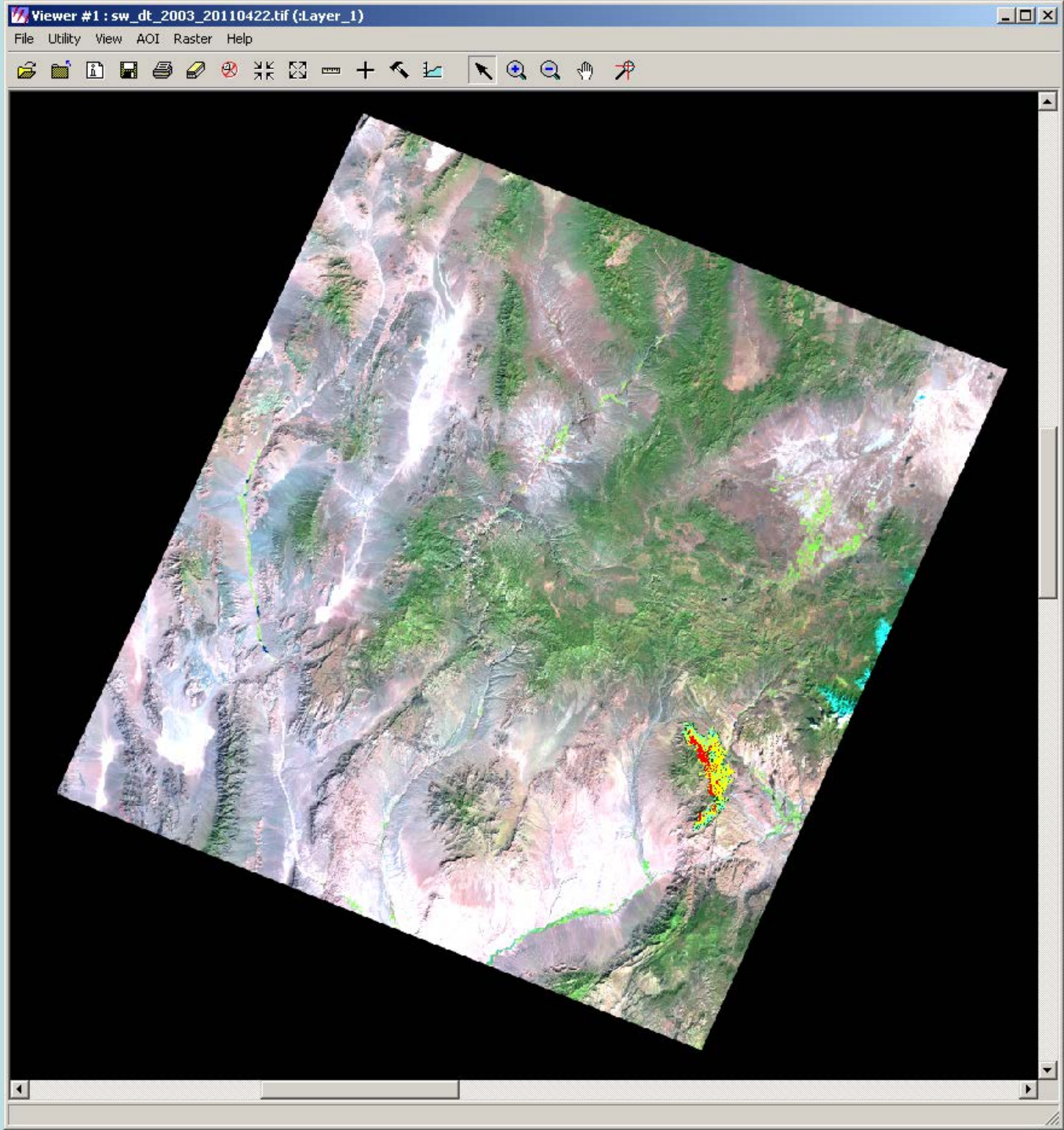
Path 39 Row 34
MTBS Fire Data 2002



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

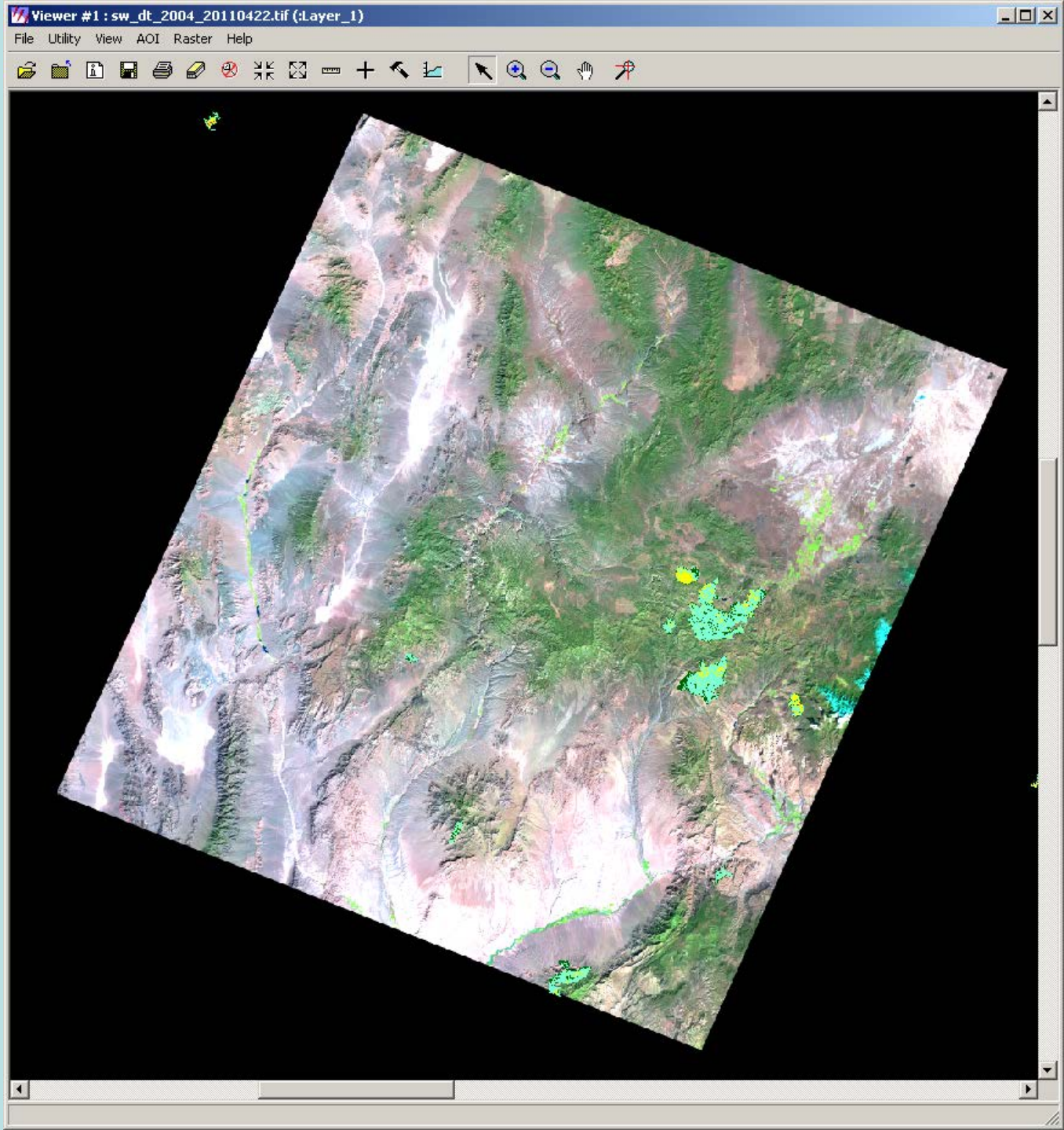
Path 39 Row 34
MTBS Fire Data 2003



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

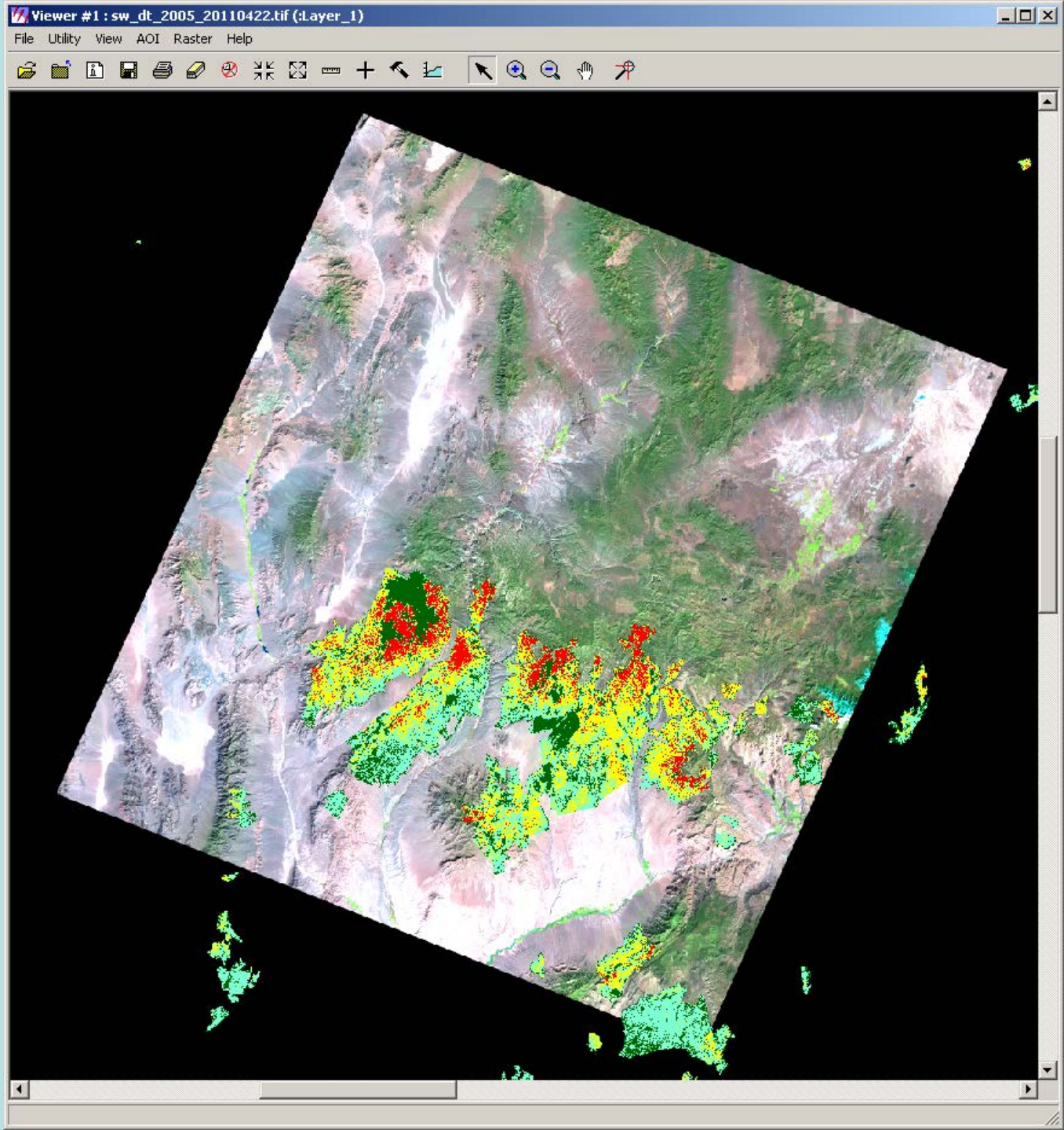
Path 39 Row 34
MTBS Fire Data 2004



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

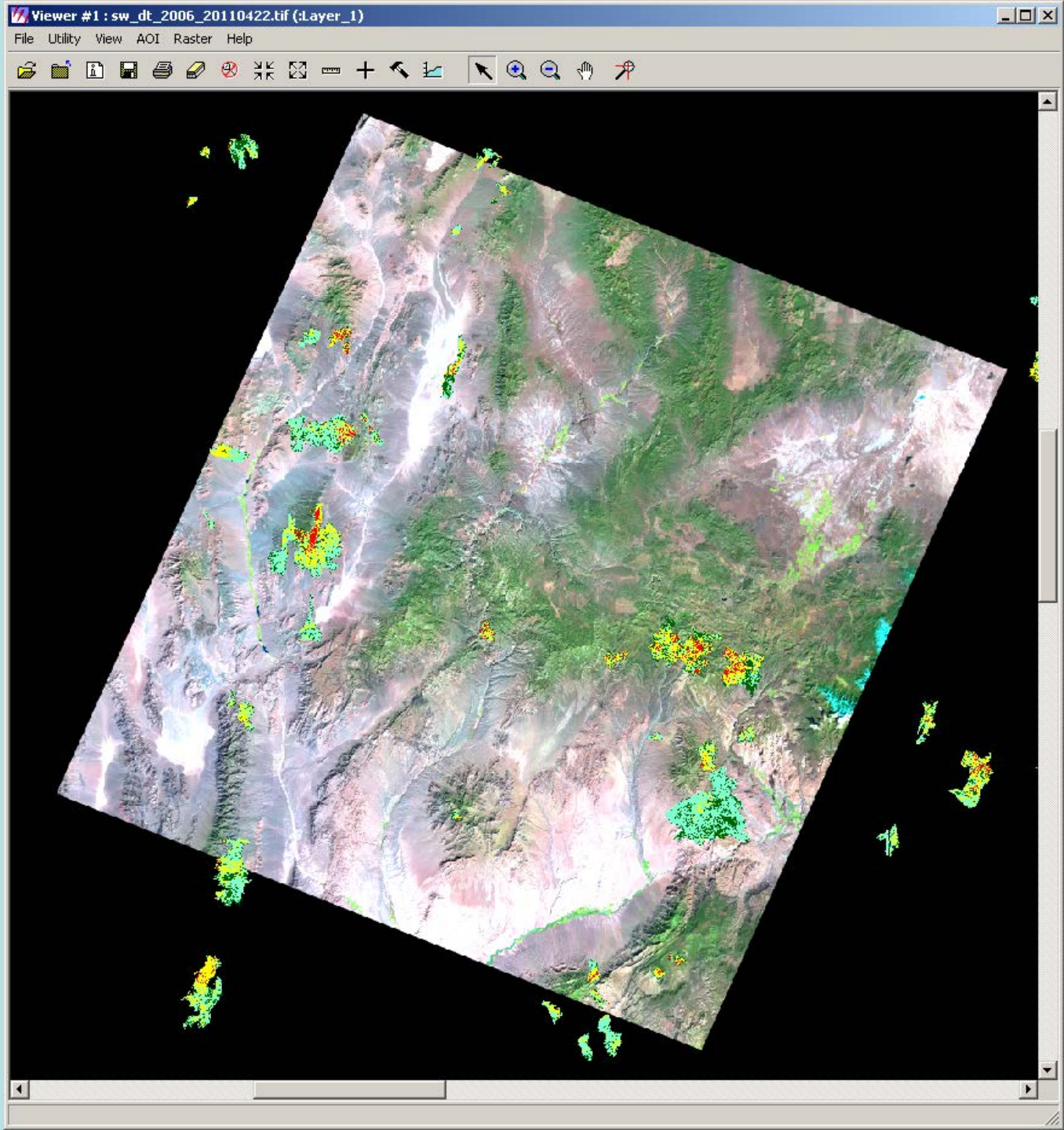
Path 39 Row 34
MTBS Fire Data 2005



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

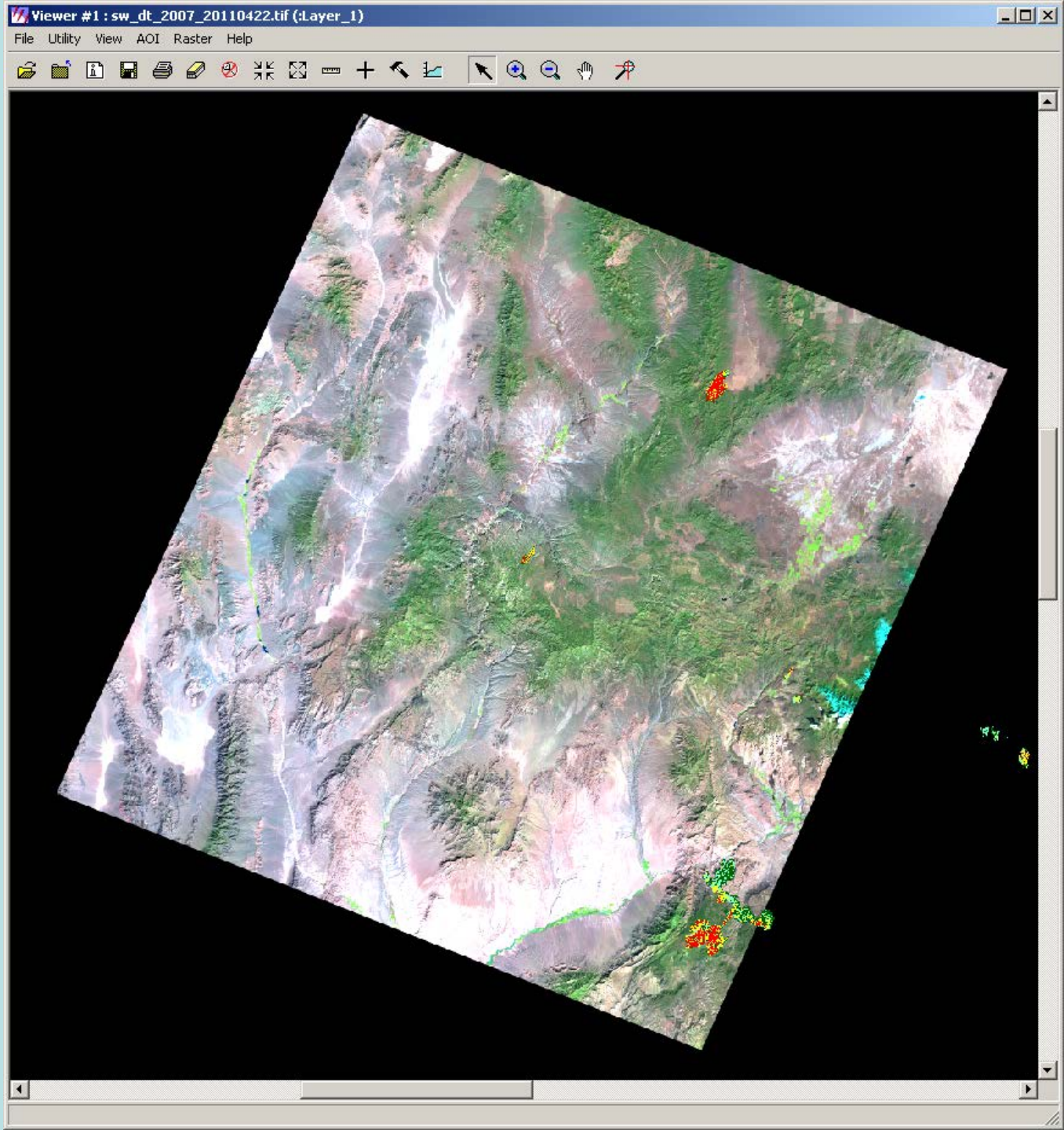
Path 39 Row 34
MTBS Fire Data 2006



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

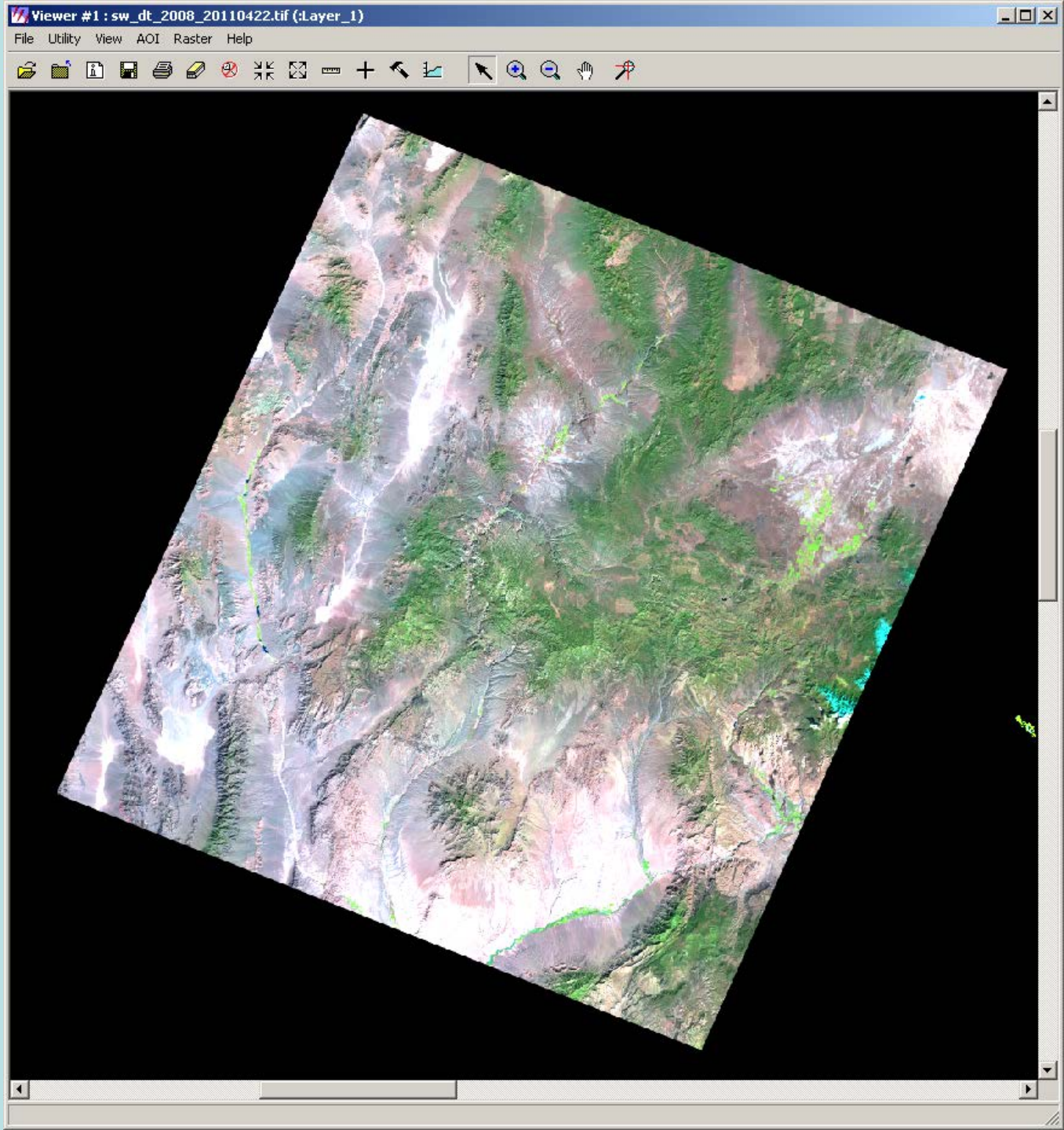
Path 39 Row 34
MTBS Fire Data 2007



Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

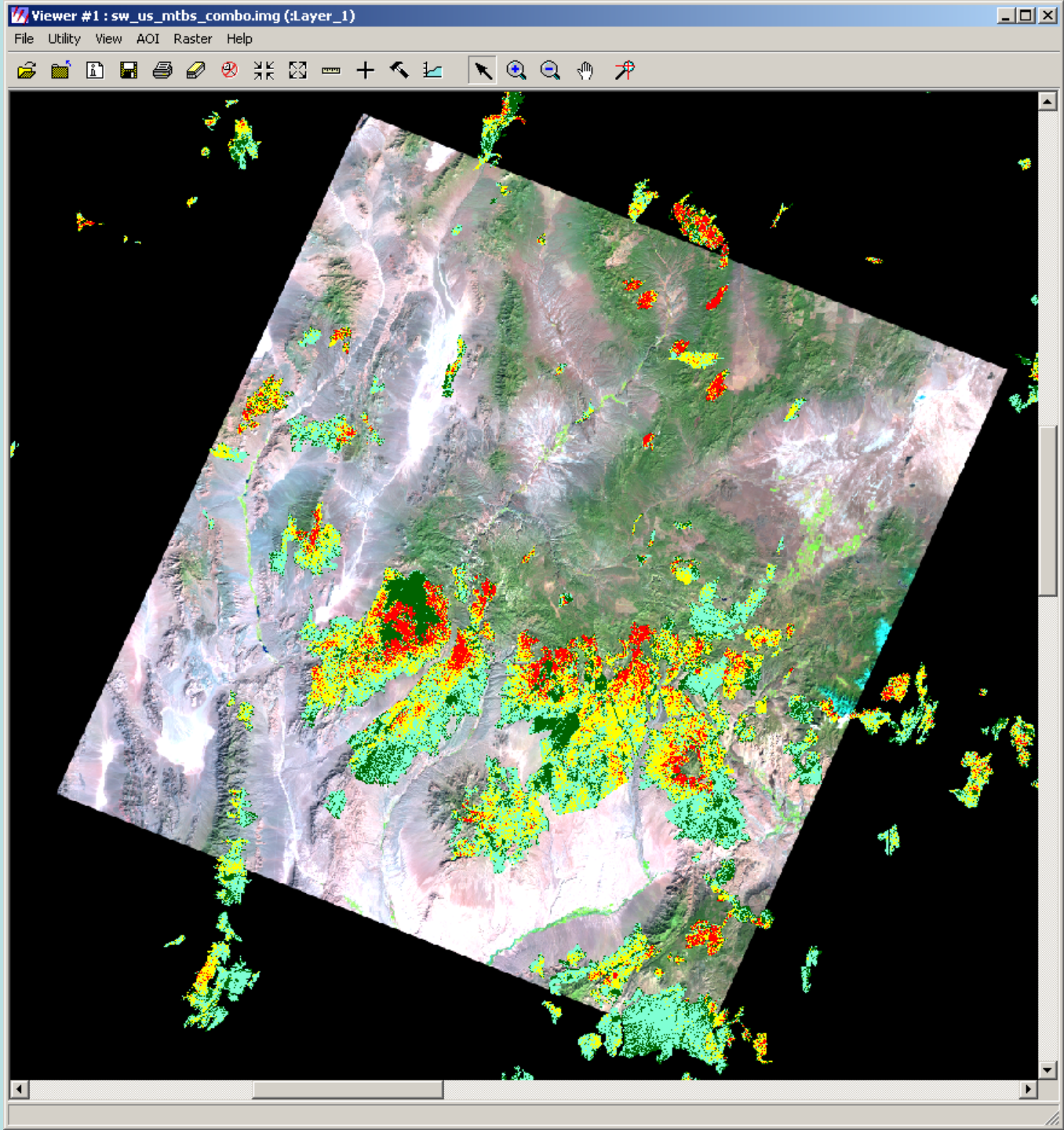
Path 39 Row 34
MTBS Fire Data 2008



Burn Severity Levels

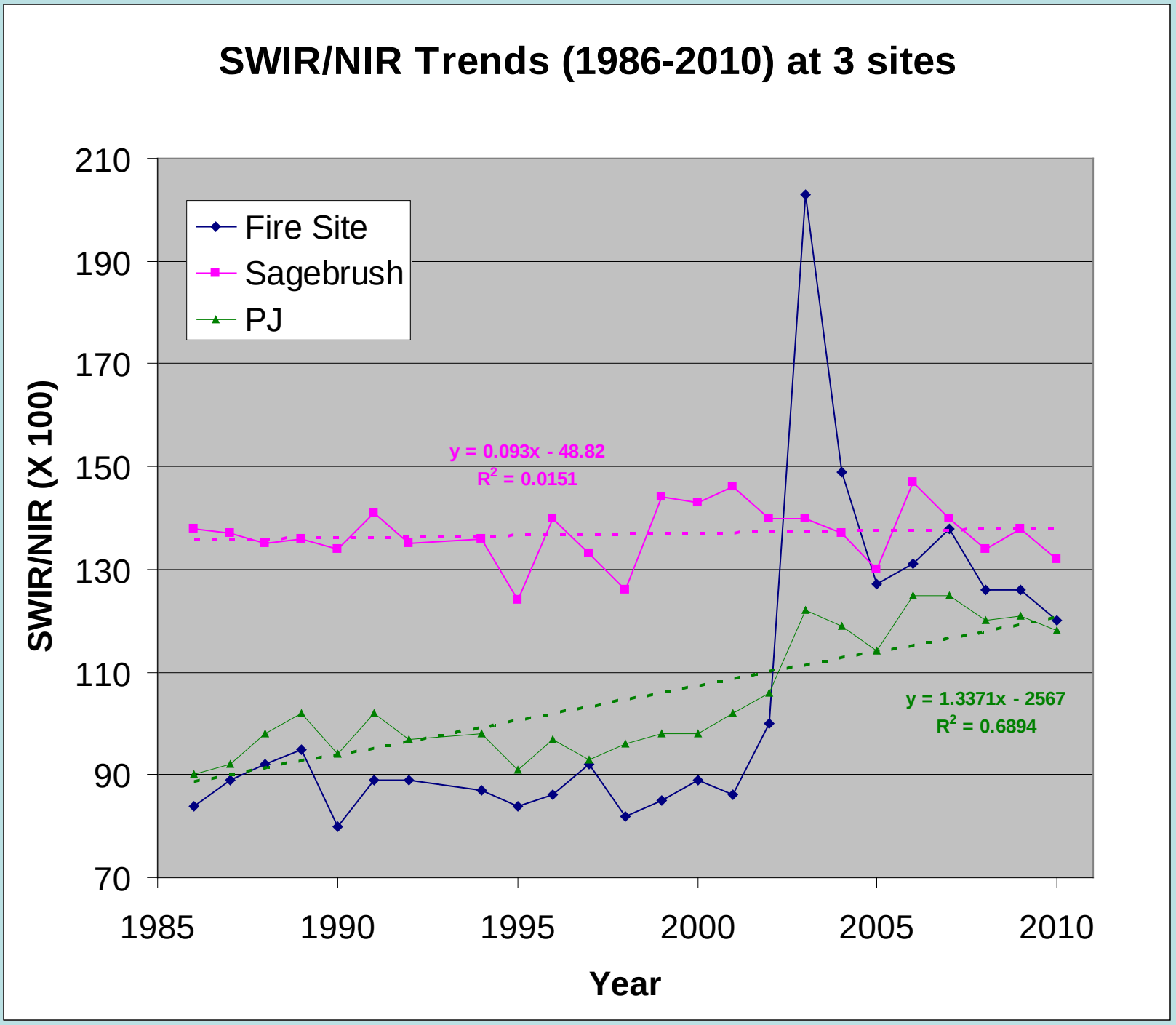
High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	

Path 39 Row 34
MTBS Fire Data All Years (composite)



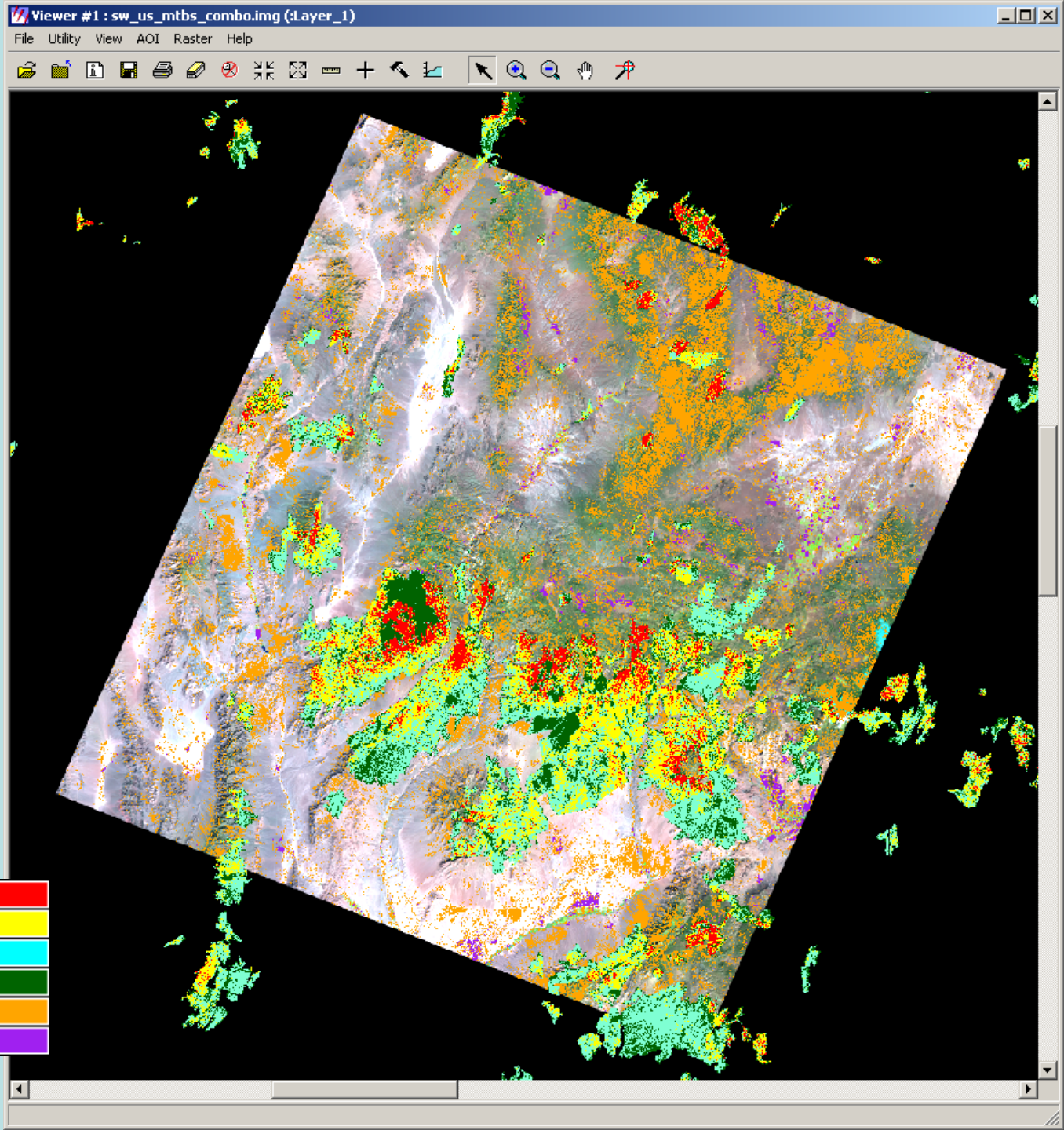
Burn Severity Levels

High Severity	
Medium Severity	
Low Severity	
Very Low/No Severity	


SWIR/NIR Trends (1986-2010) at 3 sites
Fire Site
Sagebrush
PJ
y = 0.093x - 48.82
R2 = 0.0151
y = 1.3371x - 2567
R2 = 0.6894
SWIR/NIR (X 100)
210
190
170
150
130
110
90
70
1985
1990
1995
2000
2005
2010
Year

Disturbance in south-eastern Nevada

Composite of burn severity information and long term changes in canopy cover

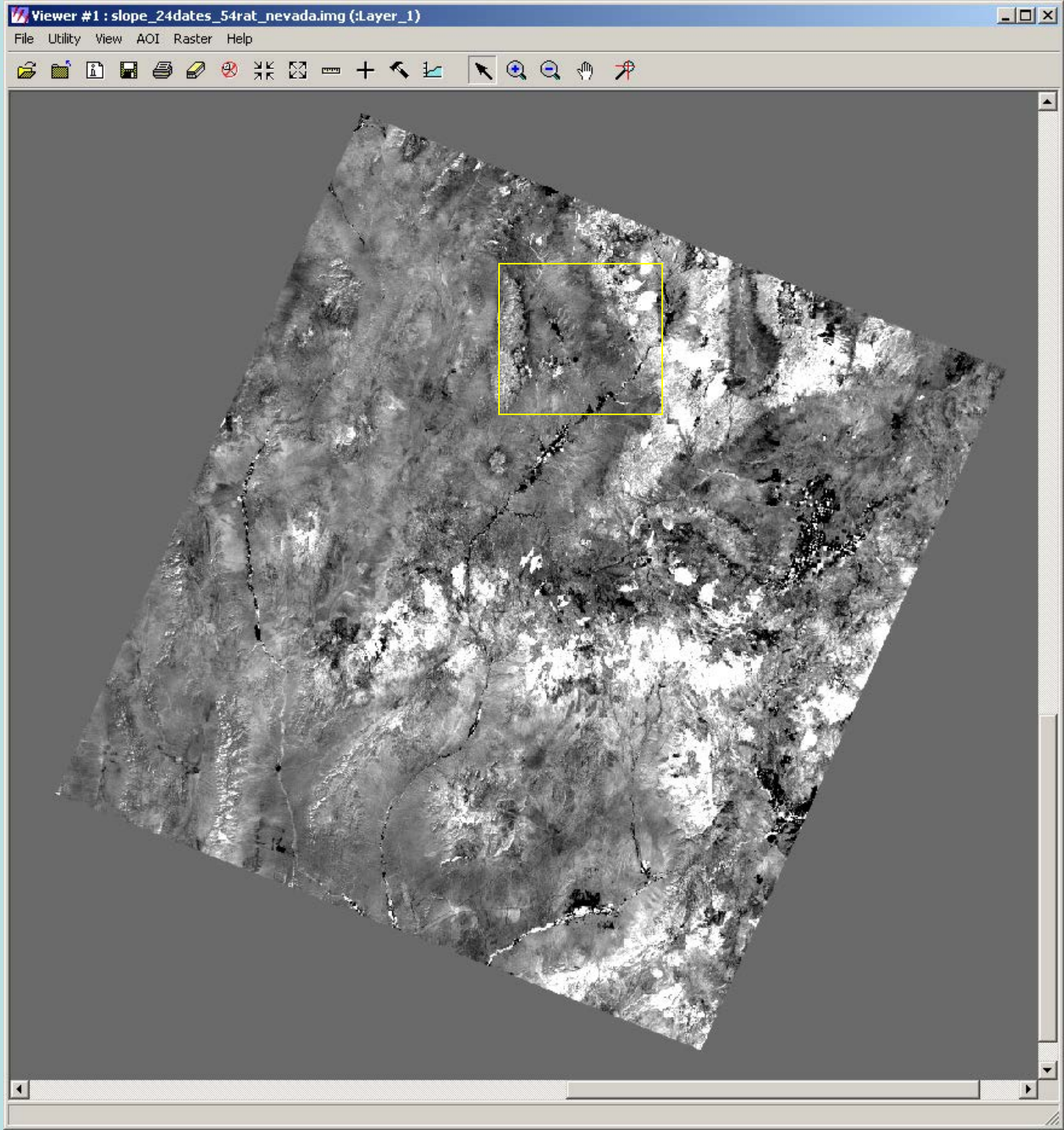


High Severity Burn	
Medium Severity Burn	
Low Severity Burn	
Very Low/No Severity Burn	
Long Term Canopy Cover Decrease	
Long Term Canopy Cover Increase	

Time versus SWIR-NIR Index Slope image (1986-2010) for south-eastern Nevada

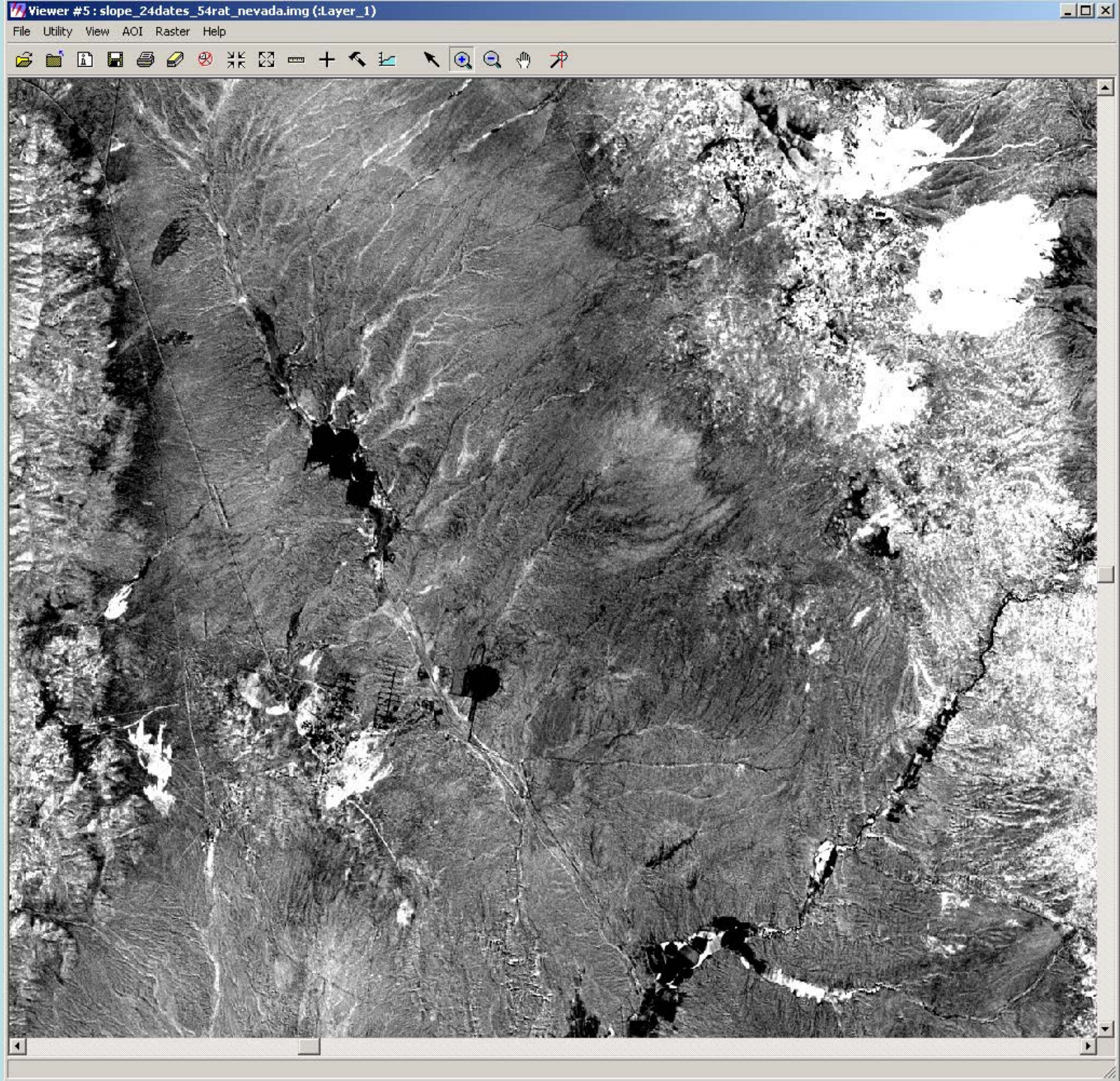
Bright areas indicate decrease in canopy cover (or decreased greenness)

Dark areas indicate increase in canopy cover (or increase in greenness)



Time versus SWIR-NIR Index slope image(1986-2010) for southeastern Nevada

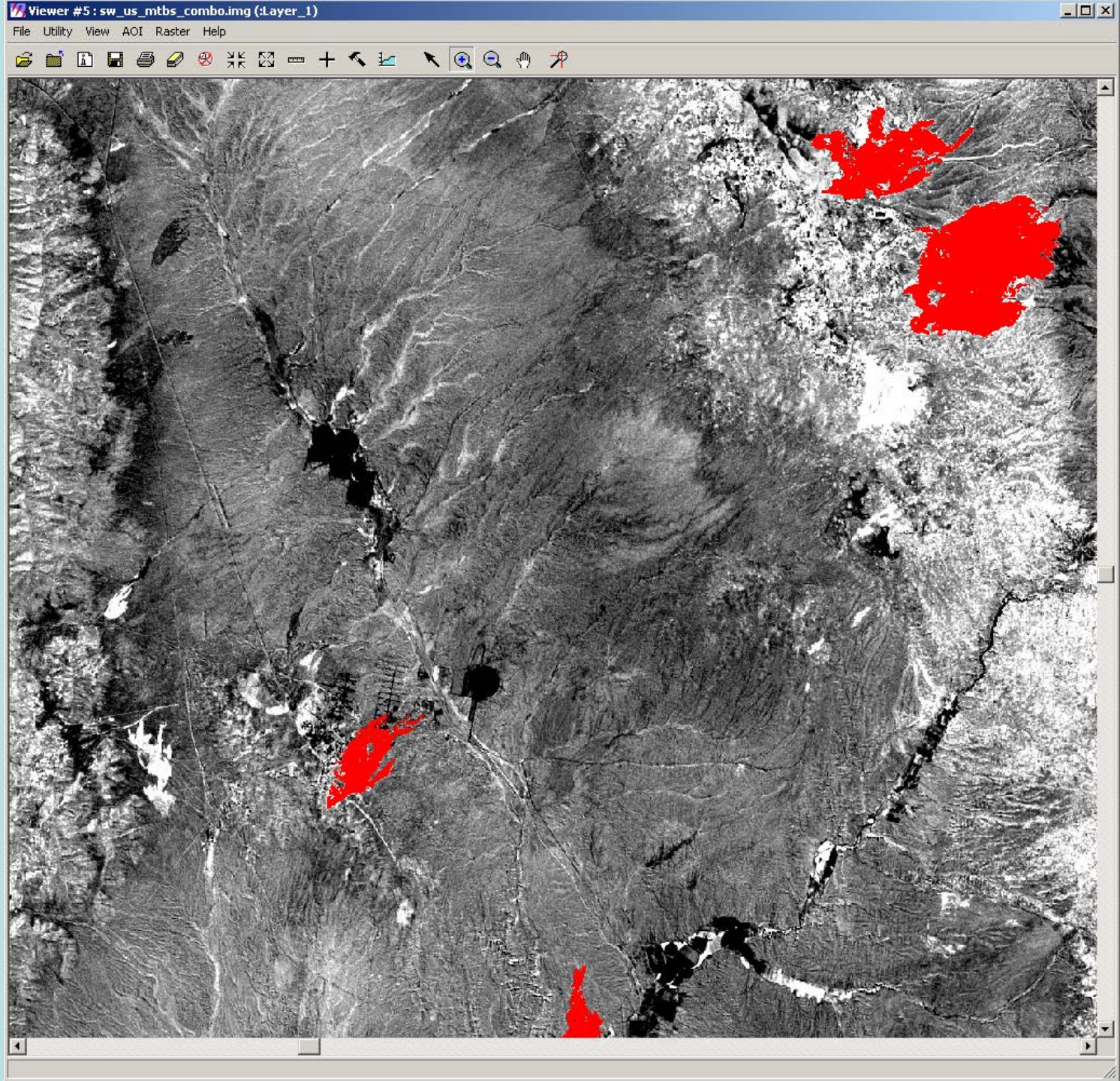
Subset of previous image



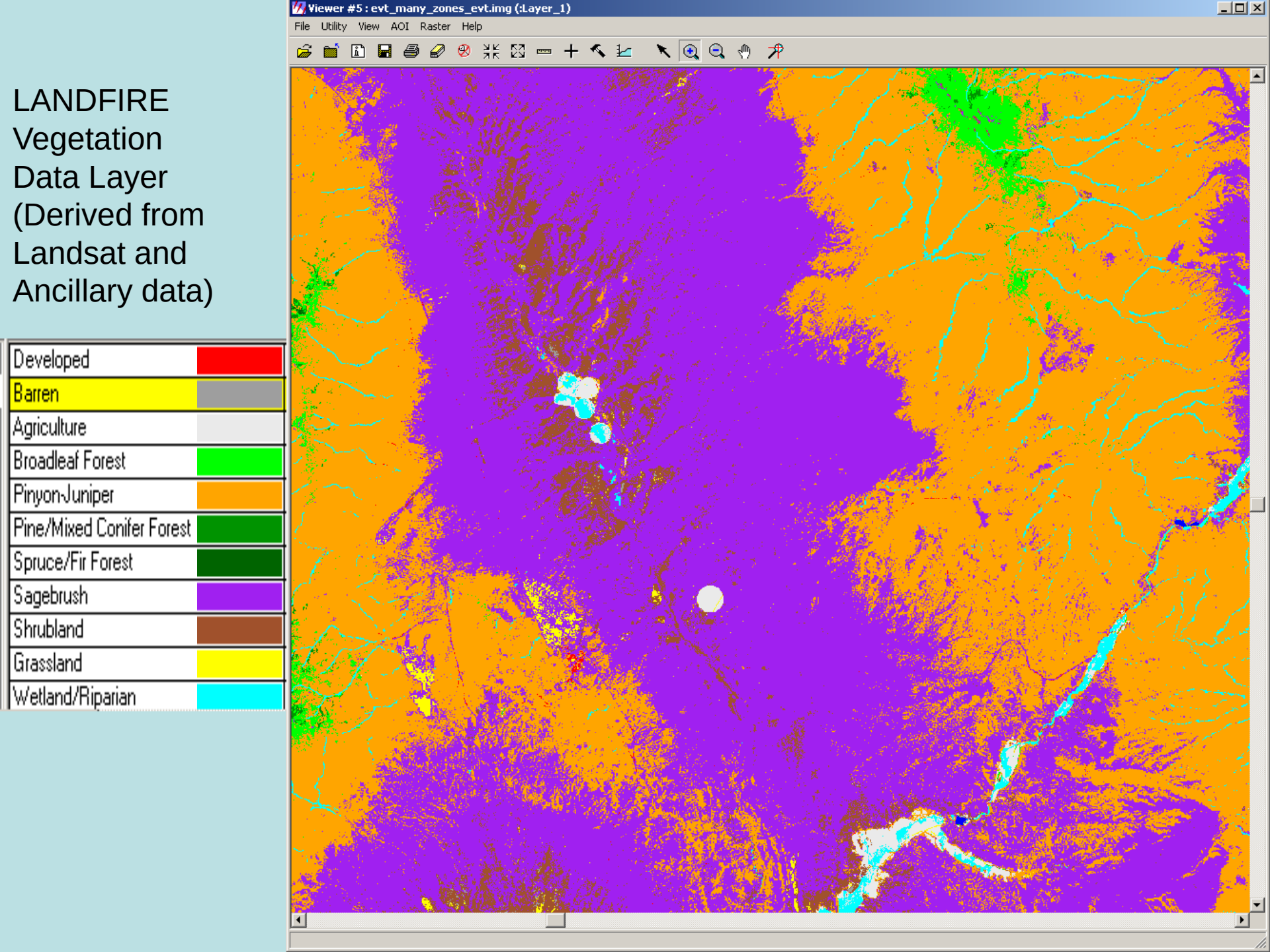
Time versus SWIR-NIR Index slope image(1986-2010) for southeastern Nevada

Subset of previous image with MTBS information overlay

Burn Area

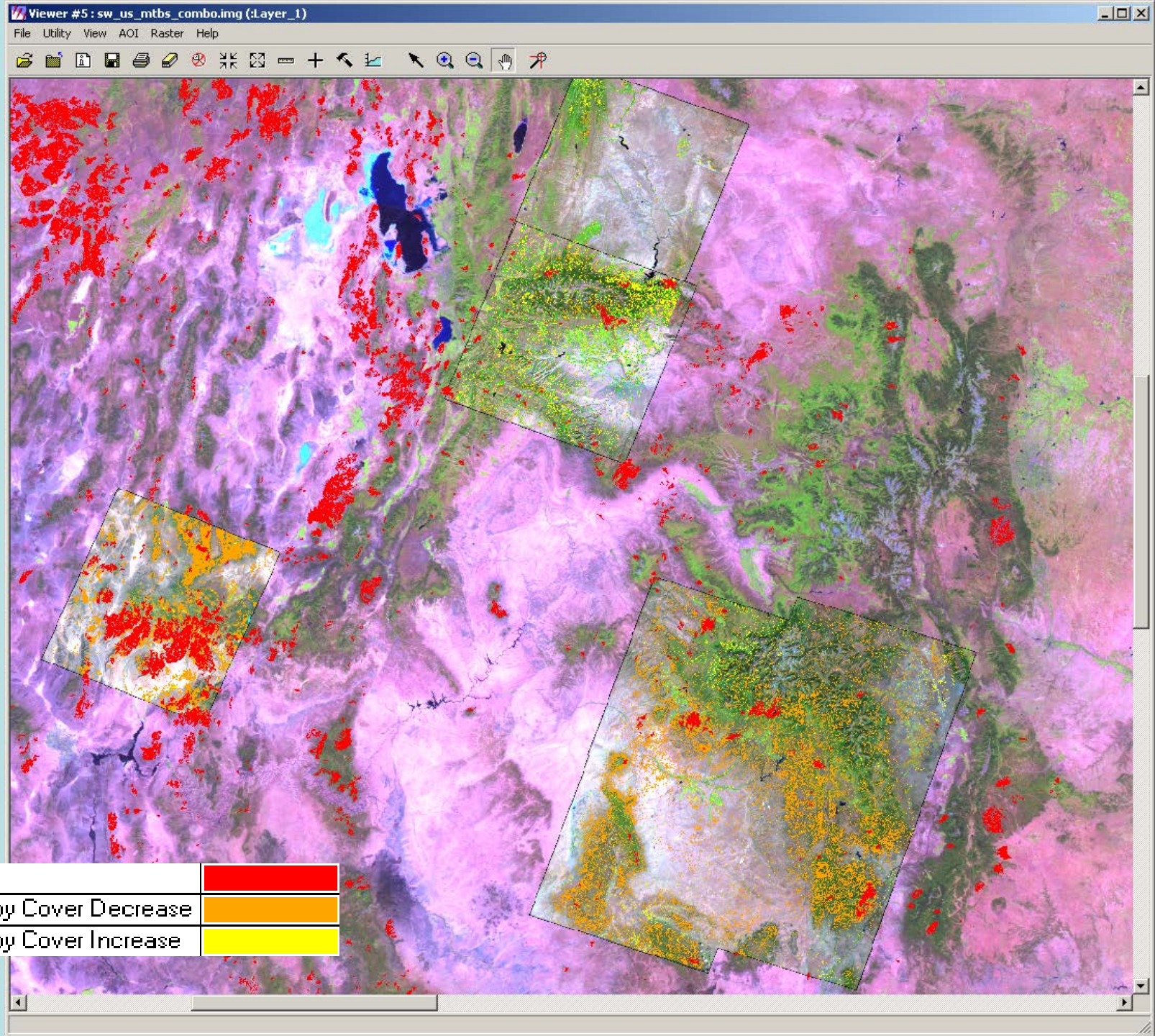


LANDFIRE Vegetation Data Layer (Derived from Landsat and Ancillary data)

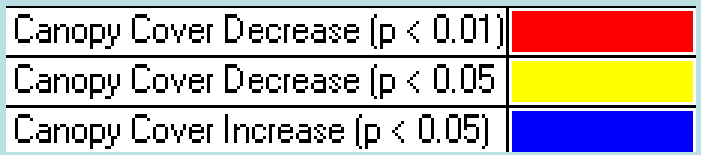


Ecosystem Changes In US Southwest

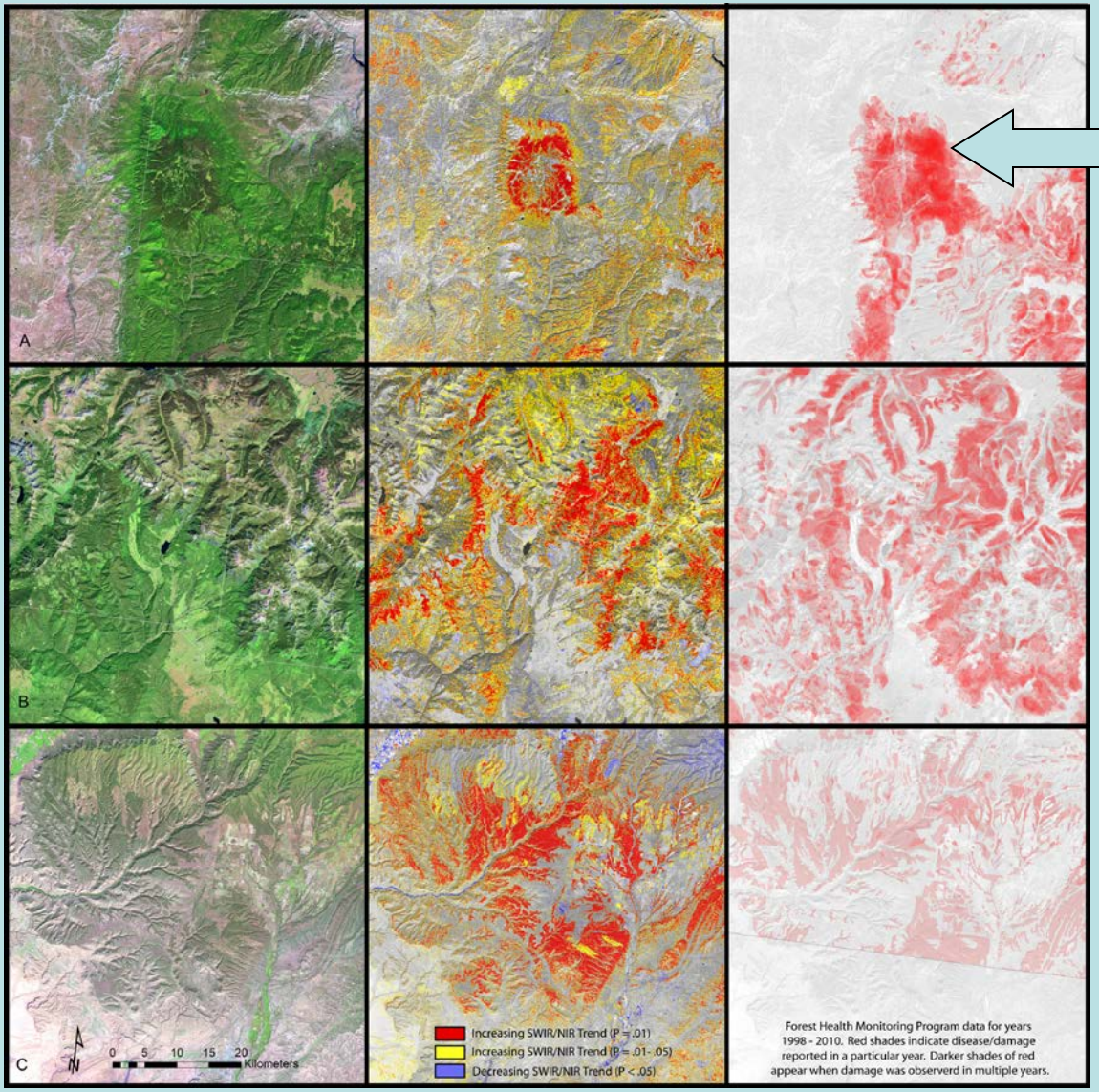
Composite of 1984-2008 burns and gradual canopy cover change (1986-2010)



Gradual Canopy Change in Four-Corners Region of US Southwest



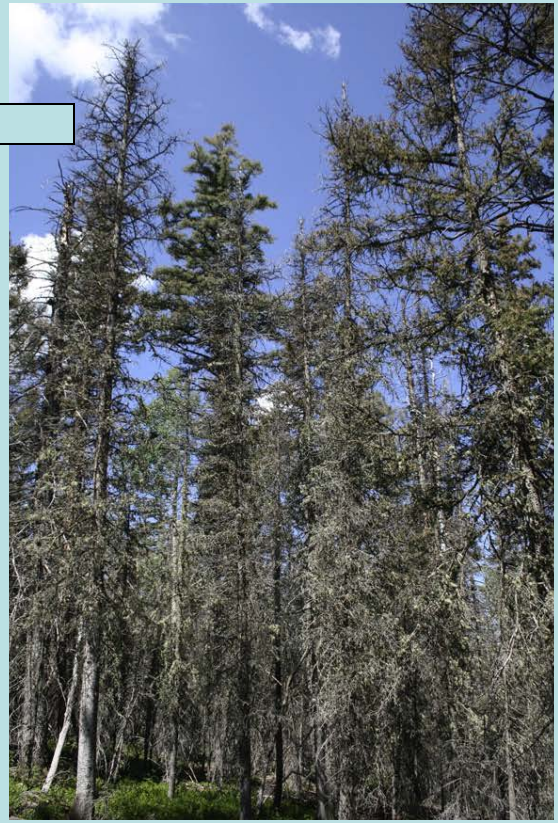
Declining Canopy Cover at Three SW Locations



TM Bands 5 4 3

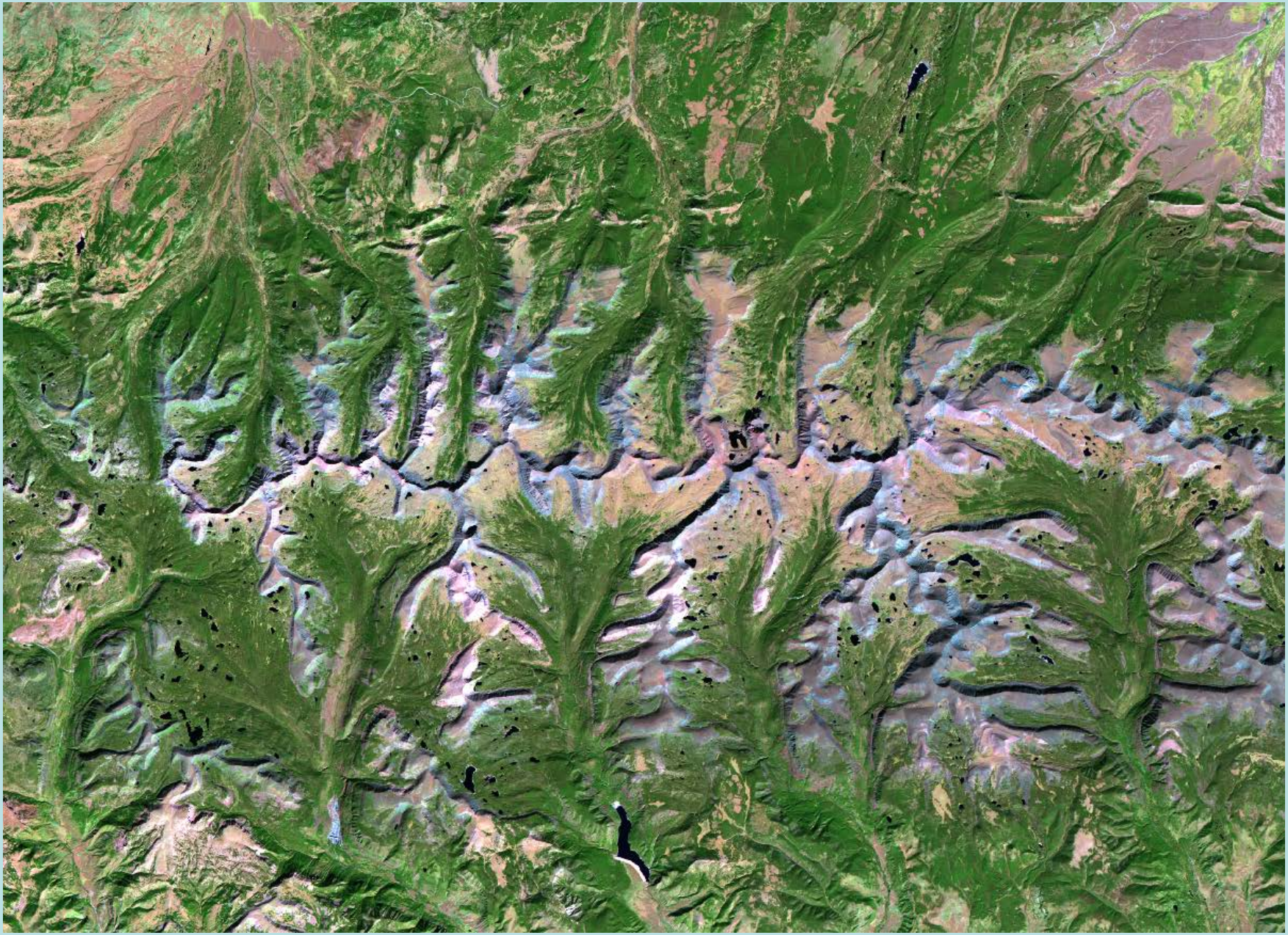
TM/ETM+ Canopy Cover Trends

Forest Health Monitoring Data

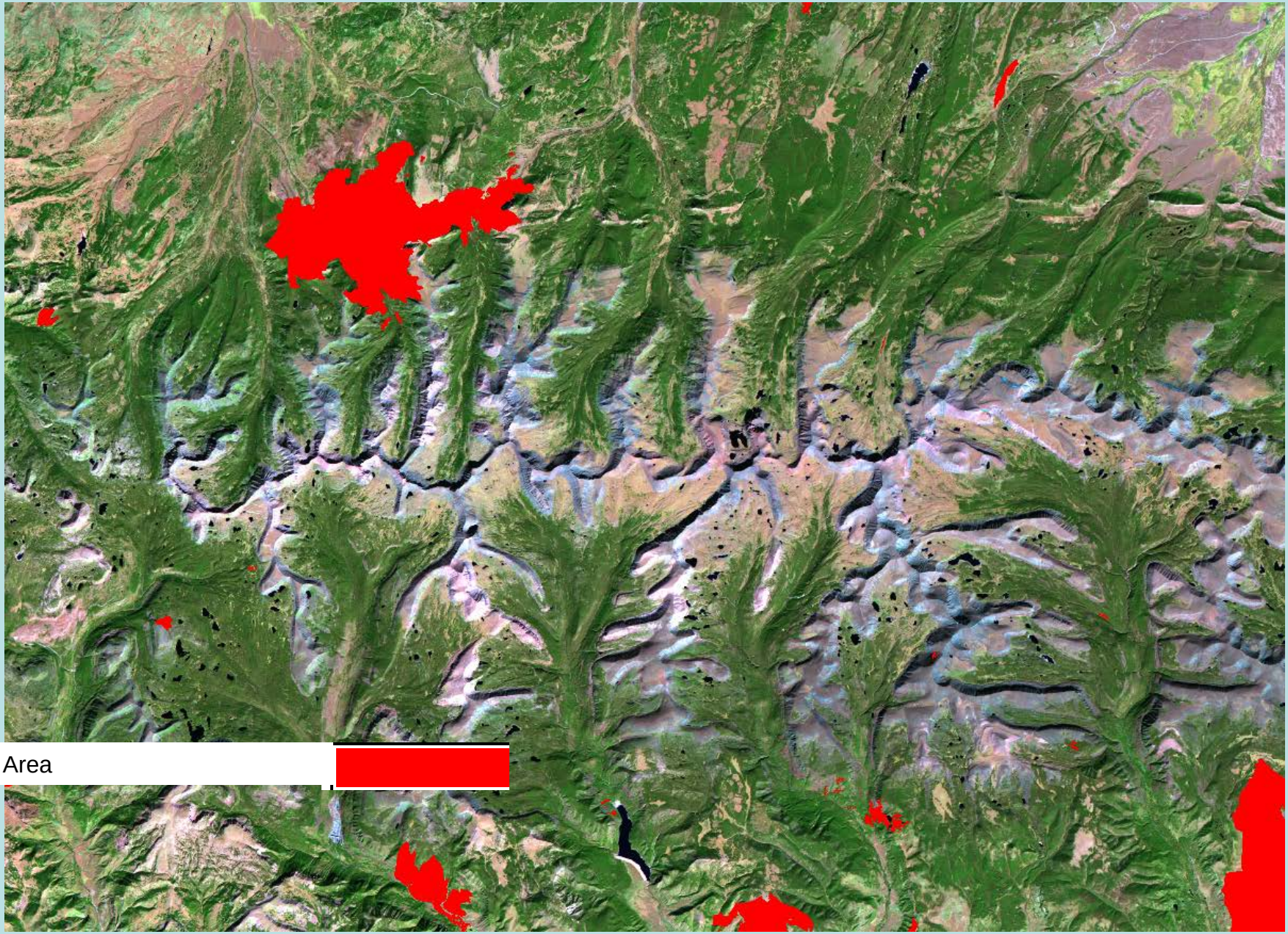


Conifer damage caused by Western Spruce Budworm (Image A)

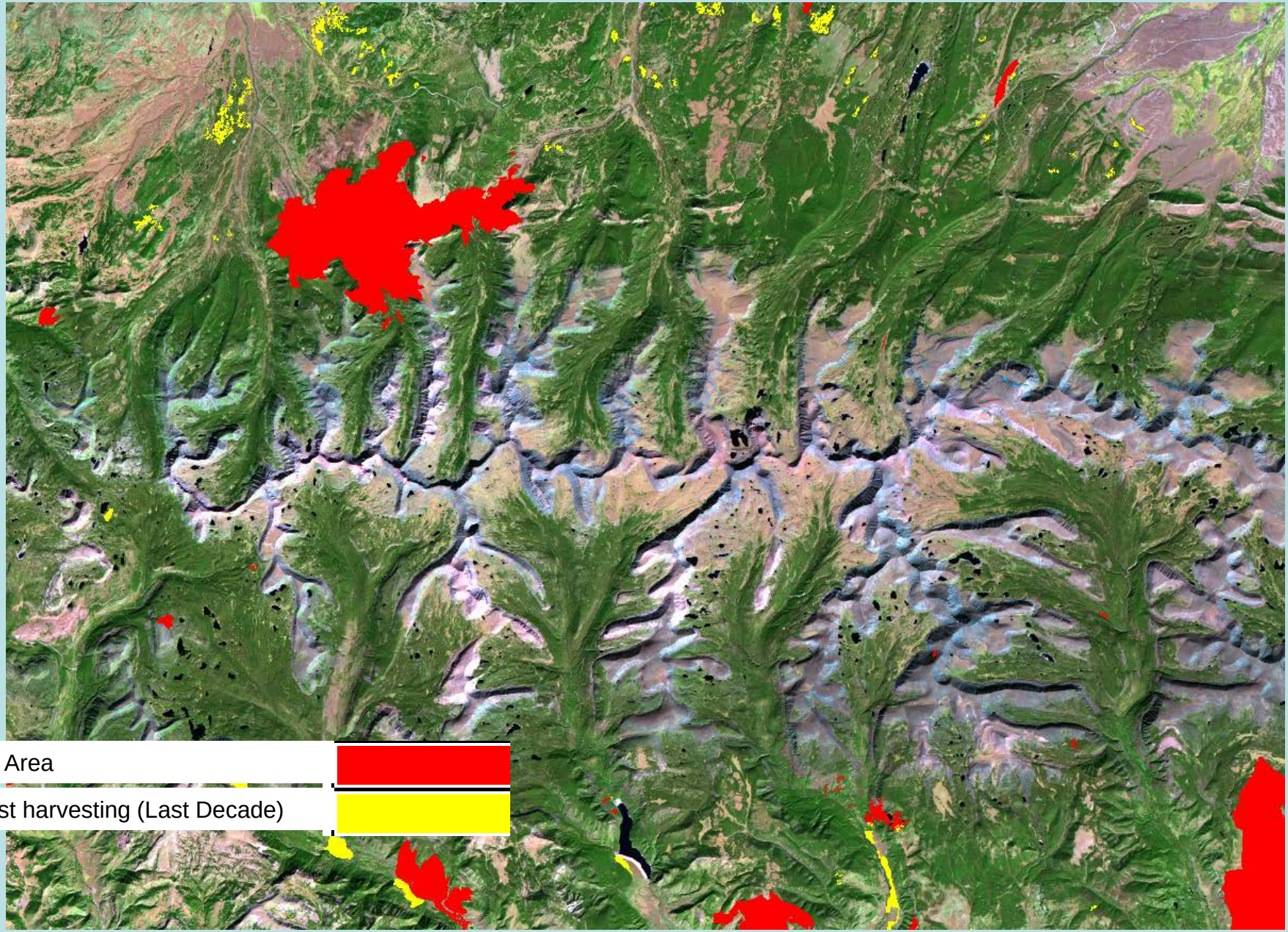
Uinta Mountains Utah (TM 5 4 3)



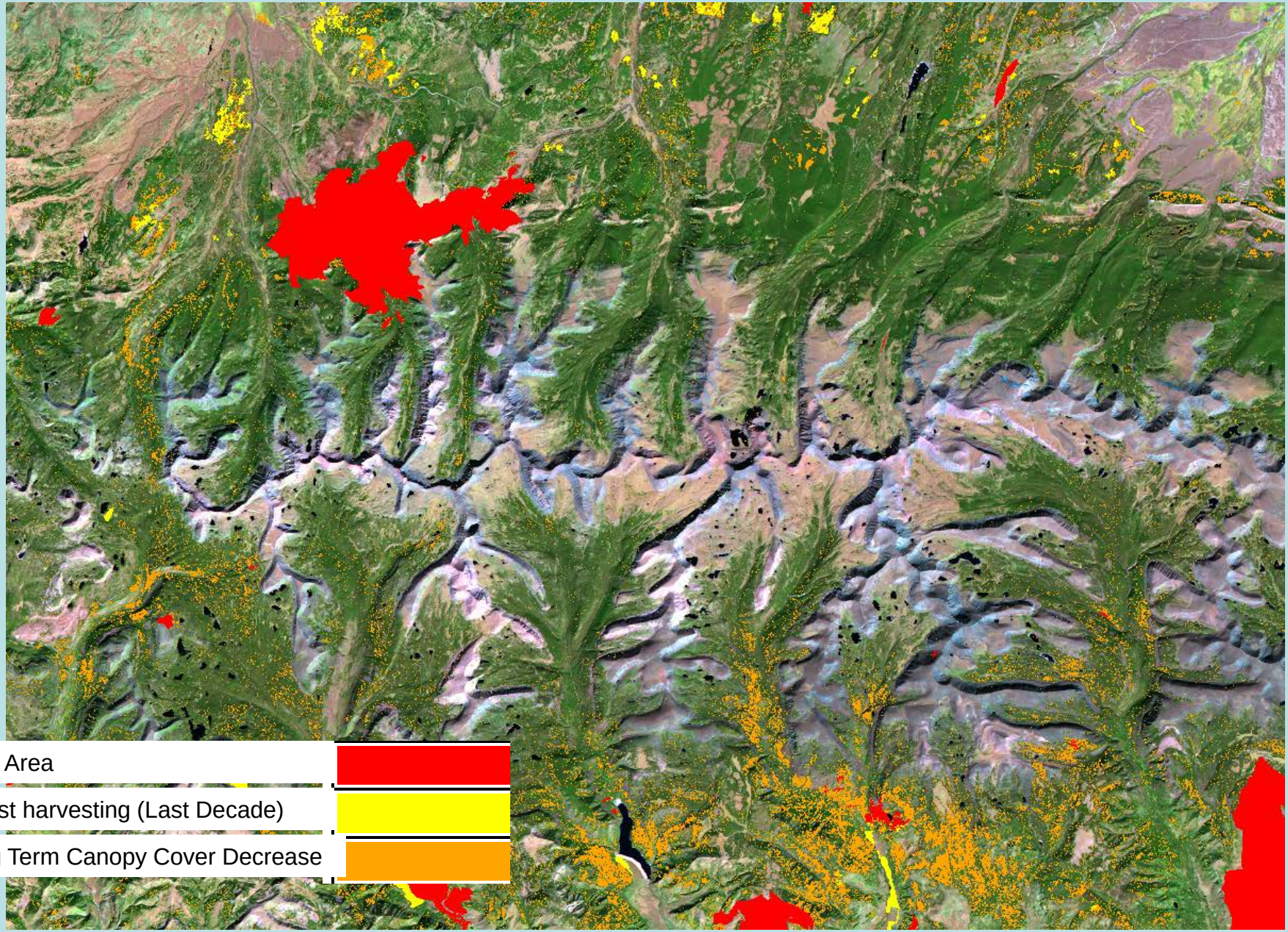
Uinta Mountains Utah with 1984-2008 MTBS data



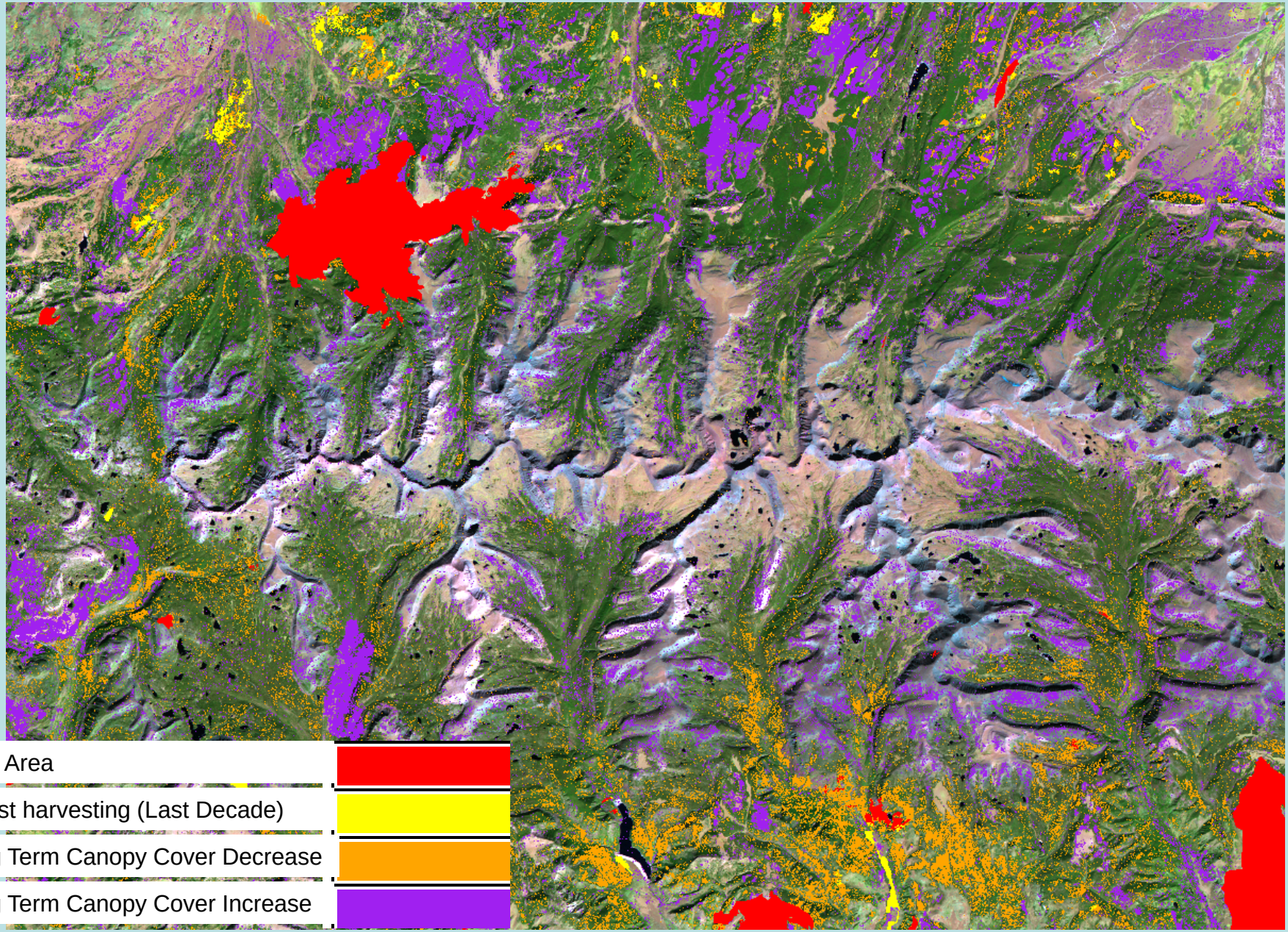
Uinta Mountains with MTBS and 2000-2008 VCT Forest Harvest Data



MTBS and VCT data and 1987- 2009 Canopy Cover (CC) Decreases

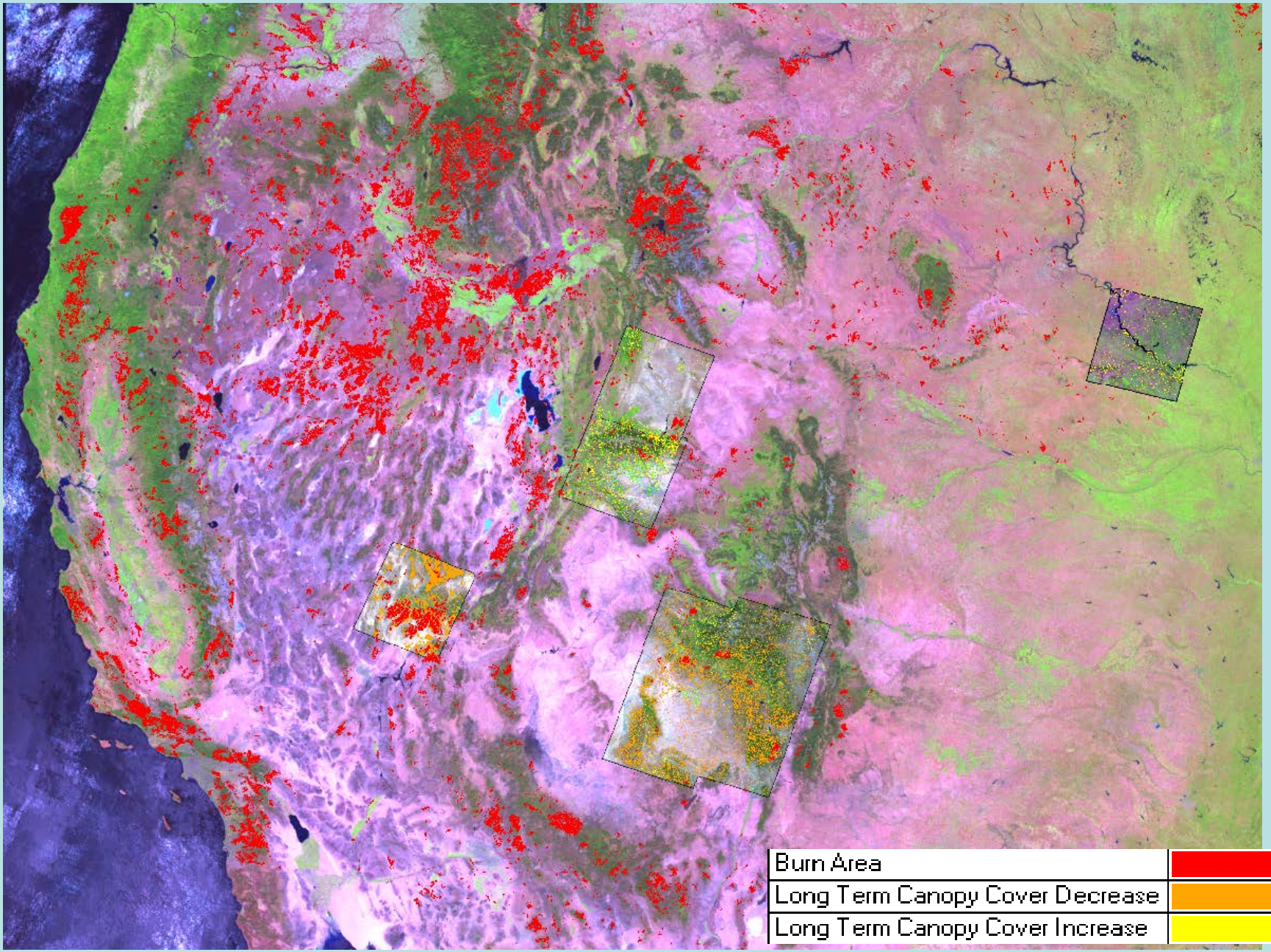


MTBS, VCT data and CC Decreases and 1987-2009 CC Increases

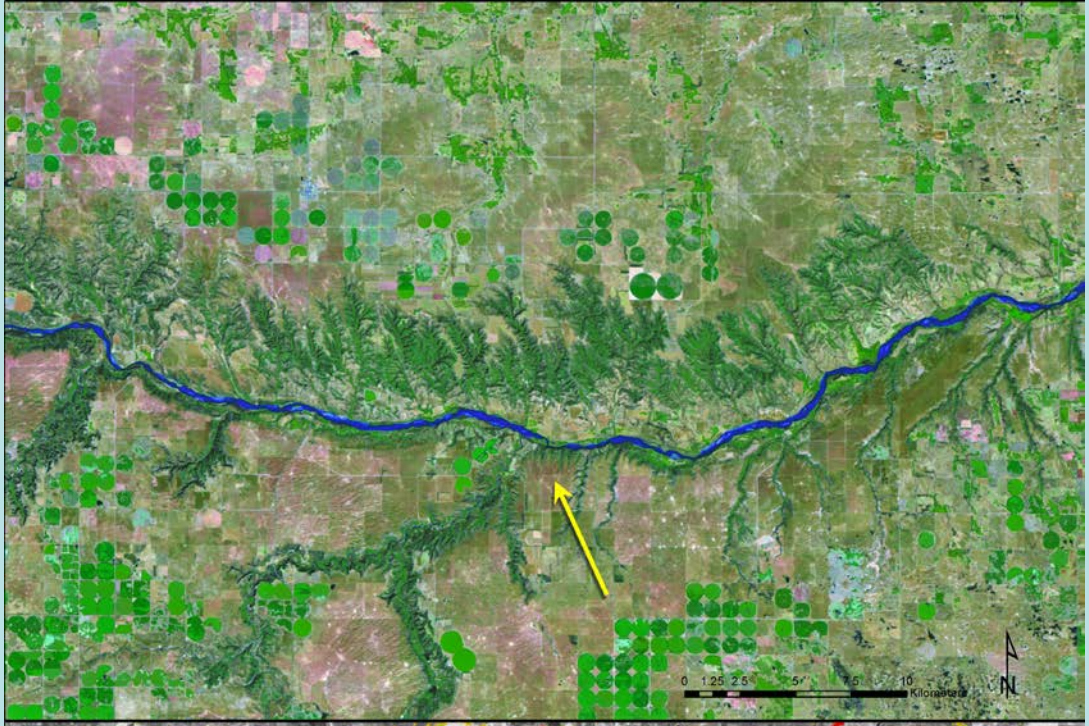


Ecosystem Changes in the Western US

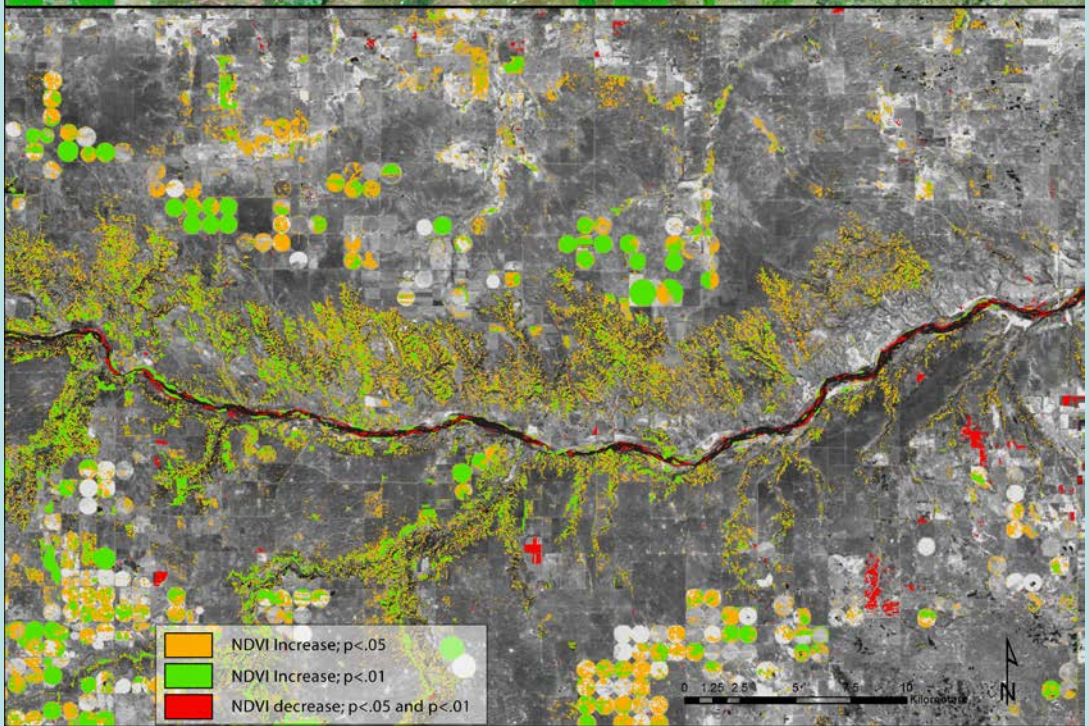
Composite of 1984-2008 burns and gradual canopy cover change (1986-2010)



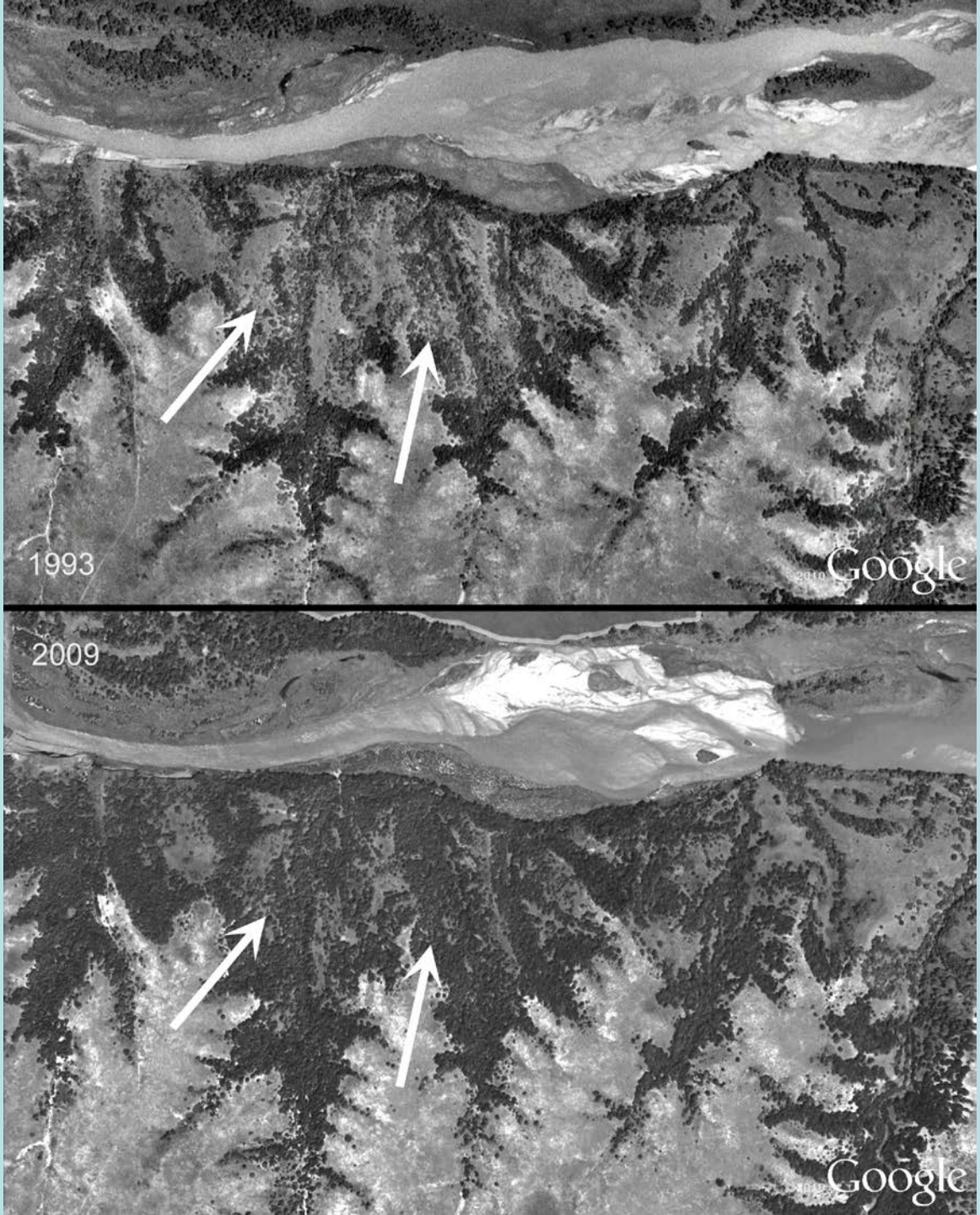
Canopy Cover Changes at Niobrara River Nebraska



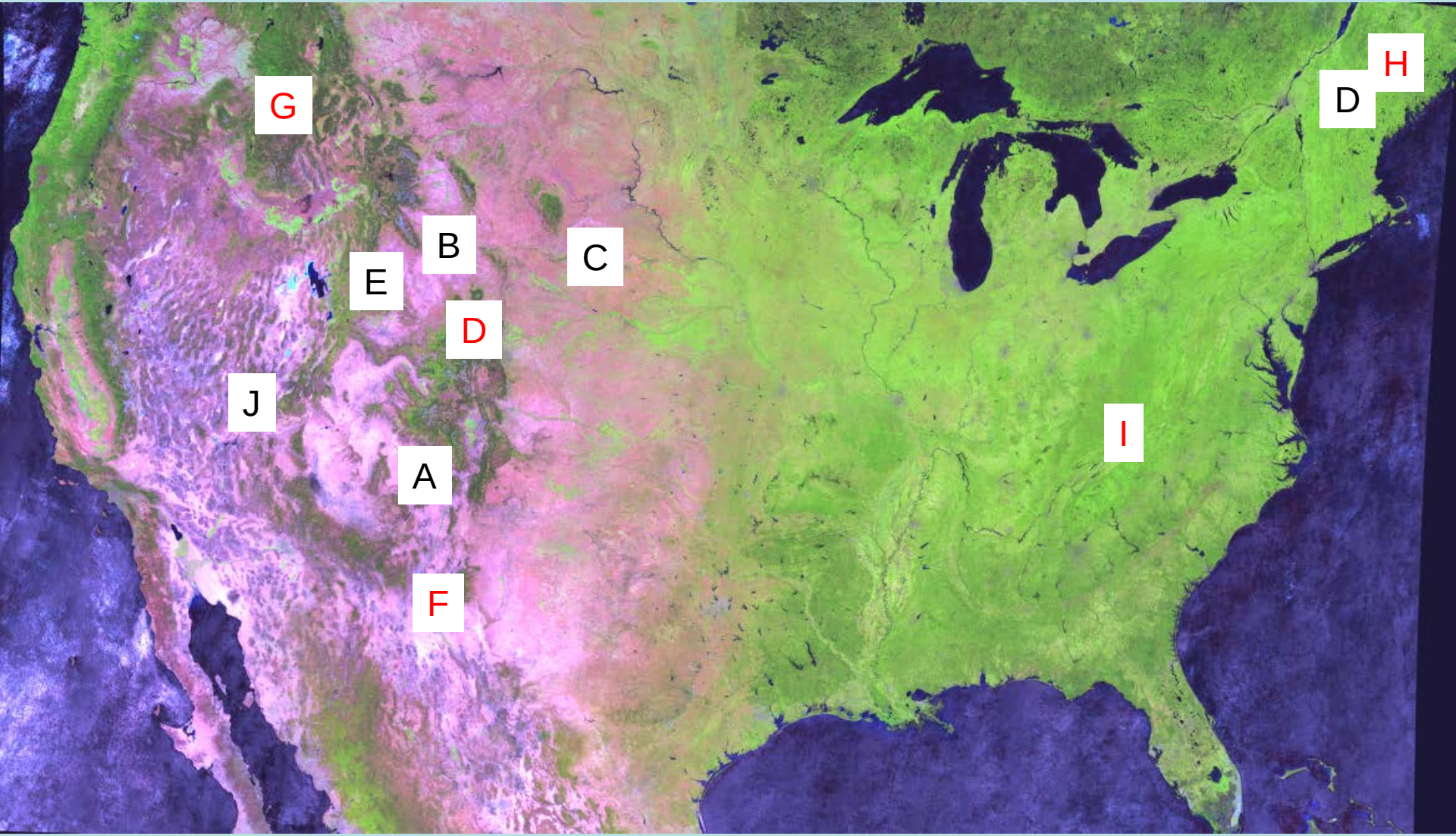
Orange and green areas indicate NDVI Increases (increasing greenness largely related to increases in eastern red cedar)



Changes in forest canopy at Niobrara River NB as seen in air photos from Google Earth



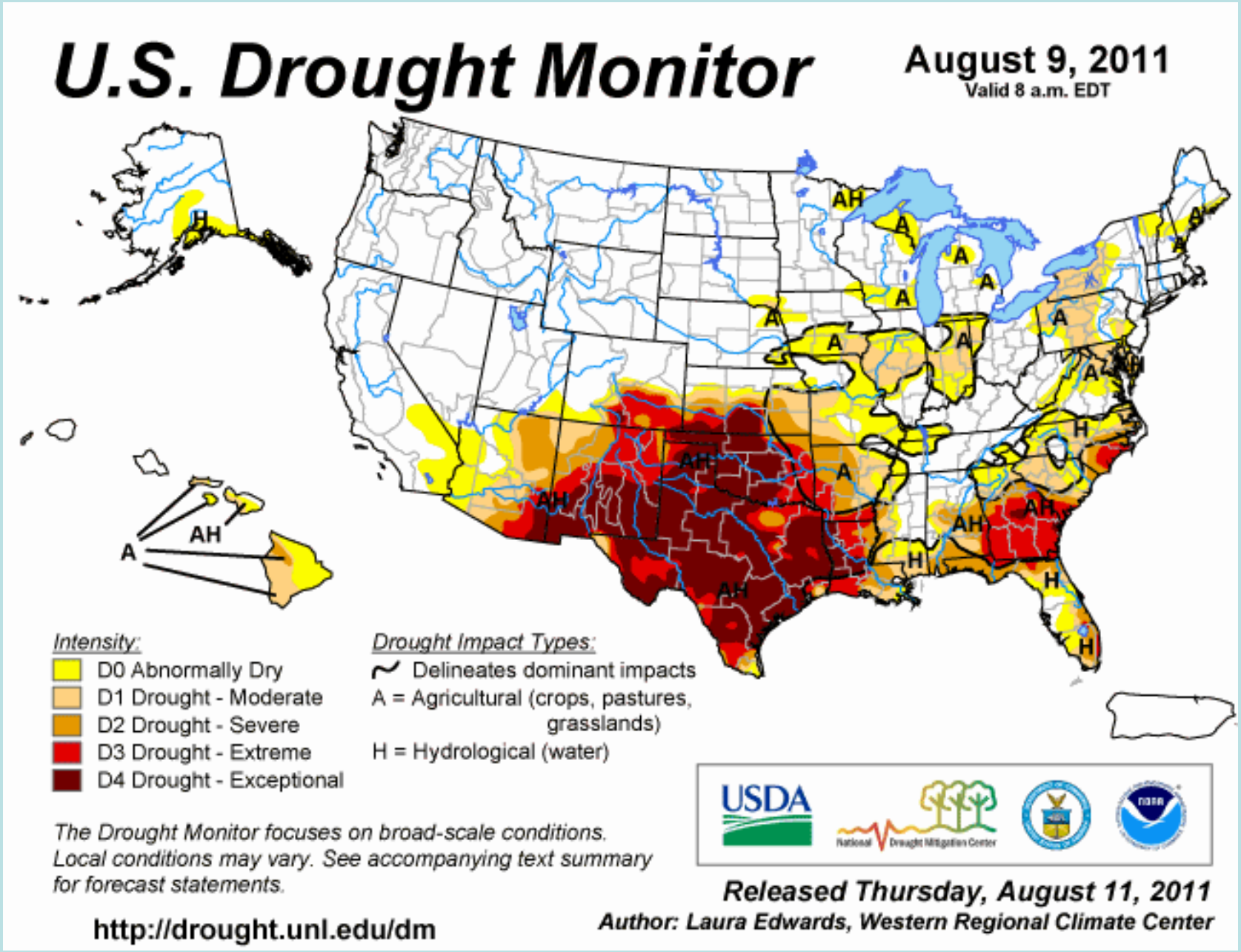
Previous/current and future study areas for Landsat time series trends analyses



What are some next steps?

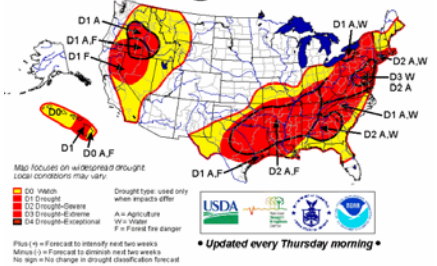
- Develop such data sets for really large regions (e.g., US) so that we can generate regional/national level perspectives of the ecological changes and trends taking place
- Develop linkages between image trends and biophysical properties of interest to various scientific communities (e.g. fire and carbon communities)
- Examine the relationships between the patterns that we are seeing and climate variables.

How do the trends correlate with existing drought information?



August 31, 1999

U.S. Drought Monitor

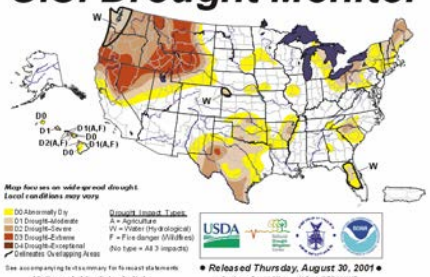


August 29, 2000 Valid 8 a.m. EDT

U.S. Drought Monitor

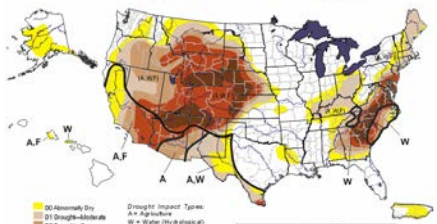
August 28, 2001 Valid 8 a.m. EDT

U.S. Drought Monitor



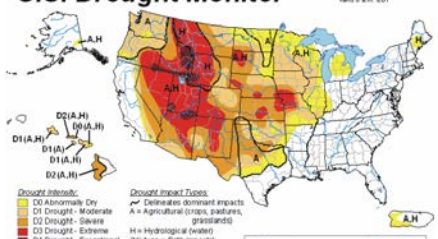
U.S. Drought Monitor August 27, 2002

Valid 8 a.m. EDT



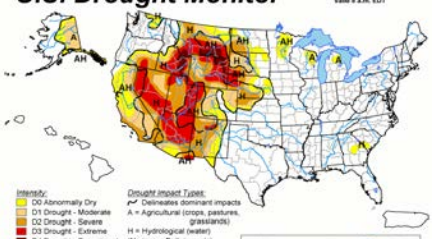
U.S. Drought Monitor August 26, 2003

Valid 8 a.m. EDT



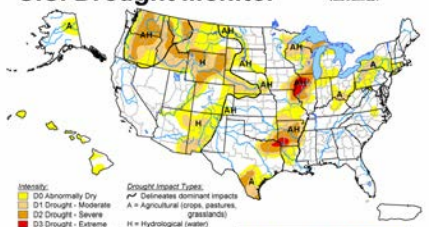
U.S. Drought Monitor August 31, 2004

Valid 8 a.m. EDT



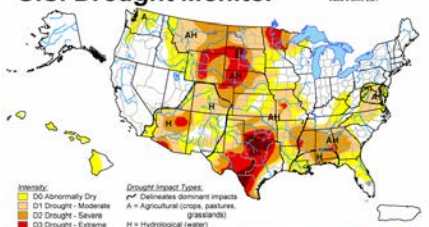
U.S. Drought Monitor August 30, 2005

Valid 8 a.m. EDT



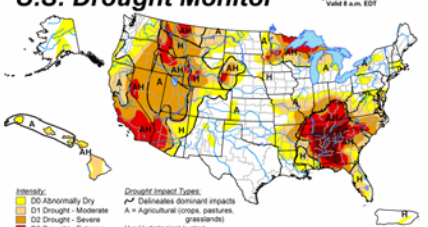
U.S. Drought Monitor August 29, 2006

Valid 8 a.m. EDT



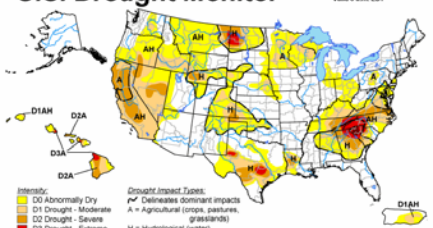
U.S. Drought Monitor August 28, 2007

Valid 8 a.m. EDT



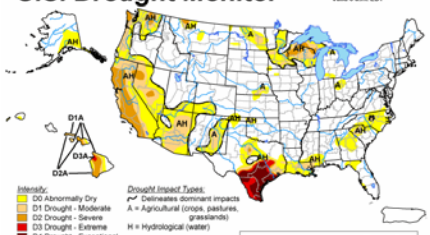
U.S. Drought Monitor August 26, 2008

Valid 8 a.m. EDT



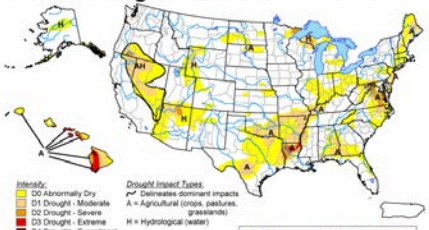
U.S. Drought Monitor August 25, 2009

Valid 8 a.m. EDT



U.S. Drought Monitor August 31, 2010

Valid 8 a.m. EDT



How do the trends correlate with existing climate information?

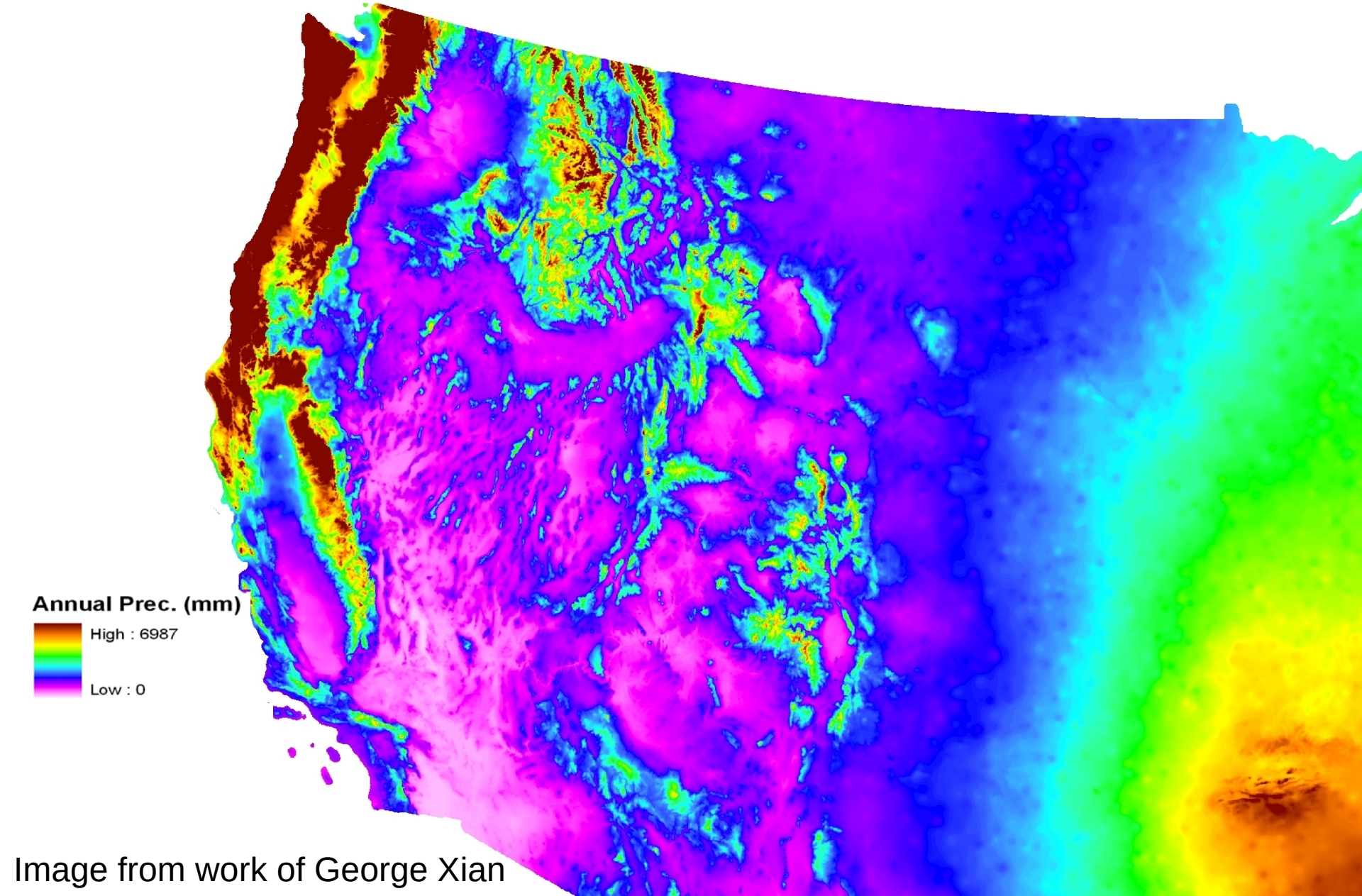


Image from work of George Xian

Image Depicting Precipitation Differences between Previous Decade and Earlier Decades

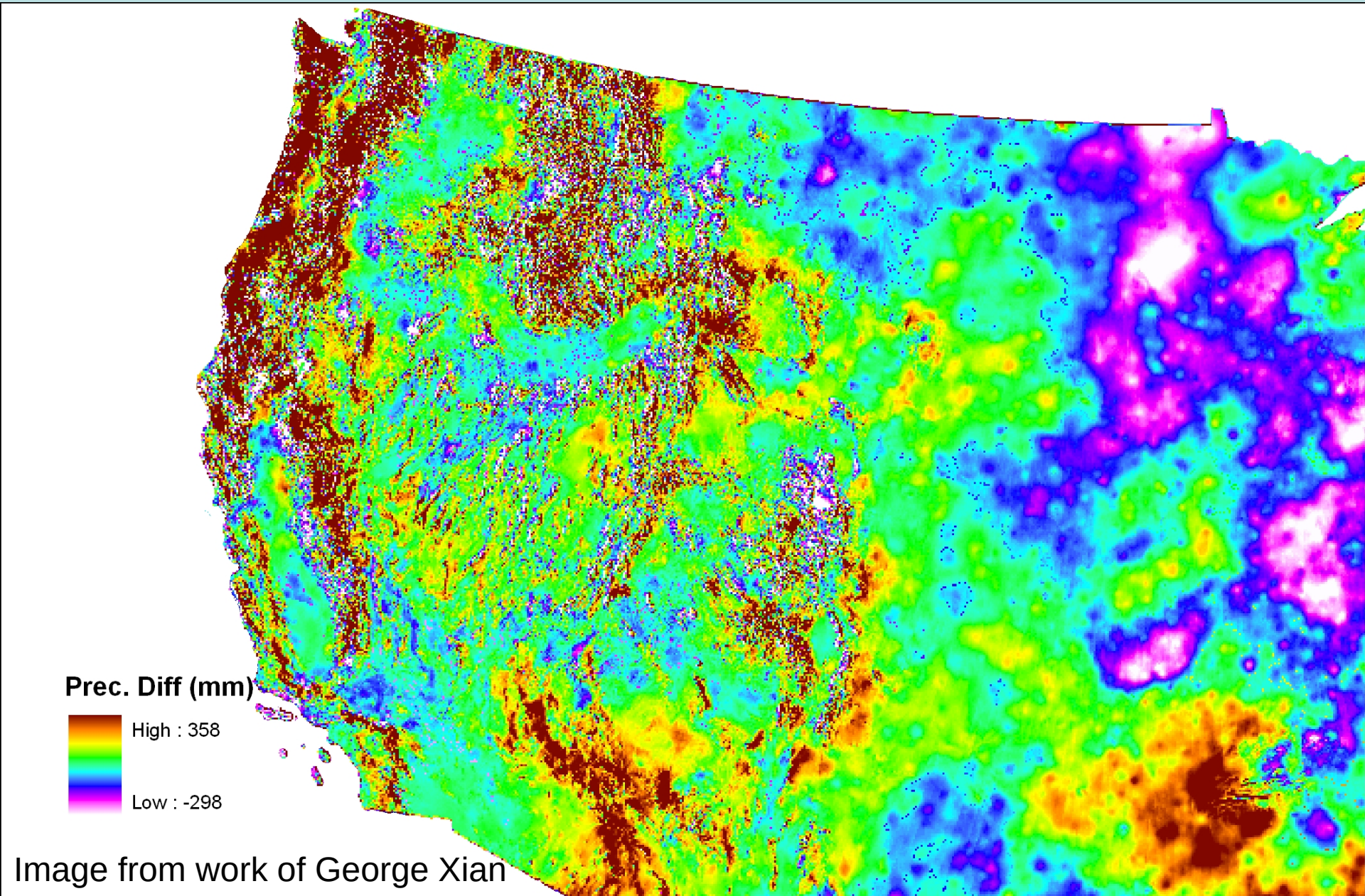


Image from work of George Xian

Graduate Thesis Topics Galore!

- Recovery rates: How fast are burn areas recovering, and what do these rates relate to?
- Vegetation transition zones: What is really happening in these zones through time?
- Biophysical parameters: From a biophysical sense, can we attribute these change areas for the fire/carbon modeling community?
- Climate variables: Can we develop more formal relationships between climate and trend information?

Joy! ☺

- **Free data!!!**
- Have used about 18,250 scenes for fire-related work
  - About 11000 scenes for VCT
  - About 5000 scenes for MTBS work
  - About 250 for gradual change work
  - About 2000 for vegetation land cover mapping work (largely NLCD)

In EOSAT dollars ($3,700-$4400 per scene) = $67,525,000 to $80,300,000

In early Landsat 7 dollars ($600 per scene) = $10,950,000

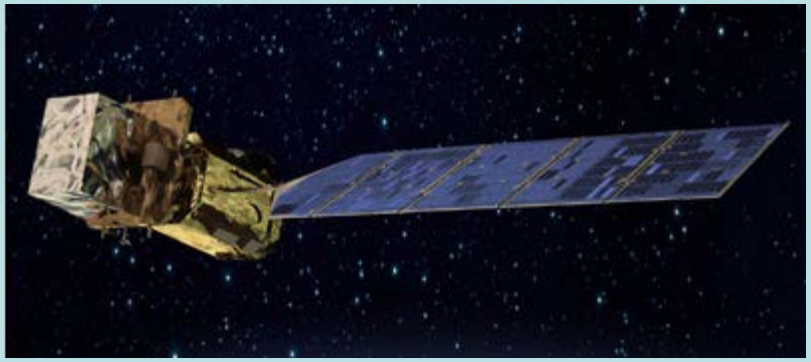
More Joy! ☺

- Sensor radiometry well-characterized
- Easy access web-enabled data
- Geometry well-characterized
- Surface reflectance becoming a reality
- Google Earth for validation
- Better algorithms for automatic trend detection (e.g., LANDTRENDR, VCT)

**All of these make analyses using multiple data sets easier and more feasible to do

A Few Acknowledgements

- Landsat Science Team (*sensu lato*), and especially to Tom Loveland, Curtis Woodcock and Jim Irons for their leadership roles
- LANDFIRE team
- Monitoring Trends and Burn Severity Team
- National Land Cover Data Team



Thank you! Bring on the launch!